DEPOSITIONAL SYSTEMS IN THE PENNSYLVANIAN CANYON GROUP
OF NORTH-CENTRAL TEXAS

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by

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THESIS

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DEPOSITIONAL SYSTEMS IN THE PENNSYLVANIAN

CANYON GROUP OF NORTH-CENTRAL TEXAS

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ABSTRACT

The Canyon Group (Missourian Series) is a sequence of westward-dipping, genetically related carbonate and terrigenous clastic facies that crop out in a northeast-southwest belt across North-Central Texas. The section includes stratigraphic units between the base of the Palo Pinto Limestone and the top of the Home Creek Limestone.

Surface and subsurface studies within thirteen counties indicate that terrigenous clastic rocks are principally component facies of high-constructive delta systems. The Perrin delta system repeatedly prograded westward and northwestward from source areas in the Ouachita Fold Belt. Algal-crinoid banks flanked the Perrin delta system on the northeast and southwest. A typical vertical deltaic sequence includes (upward) (a) organic rich, prodelta mudstone, devoid of invertebrate fossils; (b) thin, distal delta-front sandstone and mudstone, displaying graded beds, sole marks, and flow rolls; (c) thicker proximal delta-front sandstone, exhibiting contorted beds, flow rolls, and contemporaneous faults; (d) locally contorted distributary-mouth bar sandstone; and (e) distributary channel sandstone, containing abundant trough cross stratification and local clay-chip conglomerate. Thin, coal-bearing delta-plain deposits occur locally on top of deltaic sequences. All delta facies are rich in plant debris.

During delta abandonment and destruction, shallow bay-lagoon environments developed. Destructional facies include bioturbated sandy mudstone, burrowed sandstone and thin, platy argillaceous limestone with abundant invertebrate fossils. Fossiliferous mudstone units grade upward into transgressive shelf carbonate units commonly composed of phylloid algal-crinoid biomicrudite and local intraclastic biosparite shoal facies. Shelf carbonate includes onlapping sheetlike deposits; thick elongate bank deposits, which stood above the sea floor with slight bathymetric relief; massive platform carbonate; and shelf edge reef-bank accumulations.

The Henrietta fan-delta system, occurring exclusively in the subsurface of Montague, Clay, Wichita, Archer and Baylor counties, is composed of thick wedges of feldspathic sandstone and conglomerate that were deposited by high-gradient fluvial systems, which built southwestward into northern Texas from source areas in the Wichita-Arbuckle Mountains of southern Oklahoma.

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INTRODUCTION

The Canyon Group is a sequence of Upper Pennsylvanian (Missourian Series) limestone, sandstone and shale comprising delta, fan delta and shelf carbonate depositional systems. The group crops out in a northeast-southwest trending belt across North-Central Texas and dips 40 - 50 feet per mile westward into the Midland Basin.

Deltas repeatedly prograded westward across the Eastern Shelf, supplied by rivers which originated in the Ouachita Mountains. At times, deltaic sedimentation was contemporaneous with nearby carbonate bank growth. Abandoned delta lobes were transgressed by extensive shelf carbonate facies. A variety of platform and shelf-edge carbonate units accumulated in the absence of significant terrigenous sediment input. Fan deltas built southwestward into Texas, supplied by high-gradient streams originating in the Wichita-Arbuckle Mountains of Oklahoma.

Facies analysis provides insight into the nature of depositional environments of the Canyon Group; delineation of depositional systems documents the Missourian paleogeography of North-Central Texas.

The area investigated (Fig. 1) includes about 12,000 square miles of all or parts of Palo Pinto, Jack, Wise, Montague, Clay, Wichita, Archer, Young, Stephens, Shackelford, Throckmorton, Baylor and Wilbarger counties. Surface studies were concentrated in northern Palo Pinto, southeastern Jack and western Wise counties. Exposures of terrigenous clastic rocks were examined as far south as Rising Star in southern Eastland County (off the location map).

The study was initiated to define, delineate and explain the principal terrigenous clastic facies of the Canyon Group and to relate

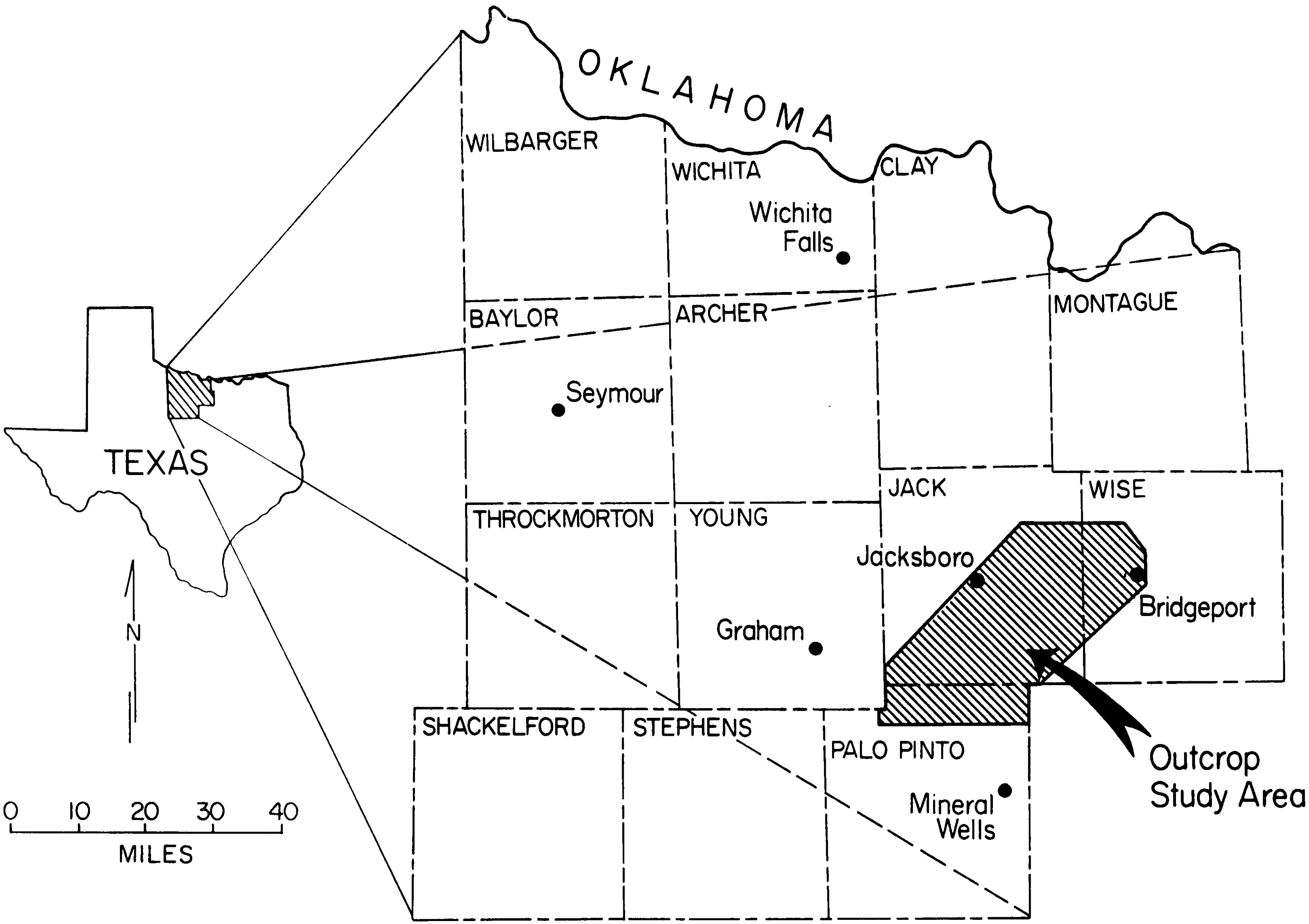


Figure 1. Location map showing areas of both surface and subsurface Canyon Group studies in North-Central Texas.

these systems to a variety of contemporaneous carbonate facies. The work was based on a rock-stratigraphic framework, and interpretations are lithogenetic.

The concept of "depositional systems" as defined by Fisher et al. (1969) comprises "... assemblages of process-related sedimentary facies. As such they are the stratigraphic equivalents to geomorphic or physiographic units" (p. 10). Depositional systems are informal rock-stratigraphic units characterized by assemblages of facies which are genetically linked by inferred depositional environments and associated processes. Recognition of depositional systems in ancient deposits is based firmly on Holocene analogues -- applying what is known about modern depositional environments and processes to interpretation of the rock record.

Methods of Study

The outcrop was mapped on stereographic aerial photographs of a scale of 1:60,000, followed by extensive field checking. A geologic map (Plate I) was constructed using a county highway map base at a scale of 1:125,000. Forty-two sections were measured and described, and critical outcrops were photographed and described in detail.

Subsurface studies involved use of 1,570 electric and sample logs in the construction of net sandstone and net limestone thickness maps for each of six Canyon Group formations. Net sandstone was interpreted and tabulated for the intervals between limestone marker units. Limestone thickness totals were obtained from the logs, and interbedded mudstone was subtracted out to give net limestone. Thickness maps were prepared at a scale of 1 inch = 16,000 feet and were later reduced to half scale for reproduction. Eight subsurface cross-sections were constructed from electric and sample logs. Two cores through the Chico Ridge Limestone in northwestern Wise County (Appendix 3) were described to provide a continuous sequence of unweathered carbonate facies.

PREVIOUS INVESTIGATIONS AND STRATIGRAPHIC TERMINOLOGY

Pennsylvanian strata in North-Central Texas were first studied by Tarr (1890), Cummins (1891), Dumble (1892) and Drake (1893) in investigations of the coal fields of the Colorado and Brazos River Valleys. Cummins (1891) applied the names Bend, Millsap, Strawn, Canyon, Cisco and Albany divisions. The Canyon division was named for Canyon station on the Texas and Pacific Railway, approximately four miles west of the town of Strawn, in Palo Pinto County. Cummins (1891) placed the base of the Canyon division at the base of the first prominent limestone and the top of the division at the top of the uppermost prominent limestone in the Brazos River Valley.

Plummer and Moore (1921) assigned formation names, including, in ascending order, the Palo Pinto Limestone, Wolf Mountain Shale, Winchell Limestone, Placid Shale, Ranger Limestone, Colony Creek Shale and Home Creek Limestone (Fig. 2). The Canyon division of Cummins' was replaced by Canyon Group, retaining the original rock-stratigraphic definition used by Cummins. The base of the Canyon Group was defined as the base of the Palo Pinto Limestone; the top of the Home Creek Limestone marks the top of the Canyon Group (Plummer and Moore, 1921). Thick limestone units and interstratified clastic facies of the Canyon Group are underlain and overlain by thick, predominantly clastic rocks of the Strawn and Cisco Groups, respectively.

Scott and Armstrong (1932) proposed new stratigraphic names for the Canyon Group of Wise County in the northern Trinity River Valley (Fig. 2). Plummer and Hornberger (1935) described the geology of Palo Pinto County and included a map of Canyon Group rock units. Lee

SYSTEM	SERIES	GROUP	FORMATION	BRAZOS RIVER VALLEY	TRINITY RIVER VALLEY
PENNSYLVANIAN	VIRGILIAN	CISCO	GRAHAM	GONZALES LS. FINIS SH.	NOT STUDIED
	MISSOURIAN	CANYON	CADDO CREEK	HOME CREEK LS. COLONY CREEK SH.	JACKSBORO LS. HOG CREEK SH.
			BRAD	RANGER LS. PLACID SH.	RANGER LS. VENTIONER BEDS
			GRAFORD	WINCHELL LS. WOLF MOUNTAIN SH.	DEVILS DEN LS. / JASPER CREEK SH. / ROCK HILL LS. — CHICO RIDGE LS. LAKE BRIDGEPORT SH.
			PALO PINTO	WILES LS. POSIDEON SH. WYNN LS.	WILLOW POINT LS. HUDSON BRIDGE LS.
	MISSOURIAN / DESMOINESIAN	STRAWN	MINERAL WELLS	KEECHI CREEK SH. TURKEY CREEK SS. DOG BEND LS. VILLAGE BEND LS.	NOT STUDIED

Figure 2. Correlation chart for Canyon Group units in the Brazos and Trinity River Valleys of North-Central Texas (See discussion for pertinent references).

et al. (1938) published significant stratigraphic and paleontologic studies of Pennsylvanian and Permian rocks in North-Central Texas, with a section on stratigraphy and paleontology of the Canyon Group.

Cheney (1940, 1945, 1947) proposed a time-stratigraphic classification for North-Central Texas Pennsylvanian rocks, in which he equated the Strawn, Canyon and Cisco Groups with the Desmoinesian, Missourian and Virgilian Series of the Mid-Continent area, respectively. Group boundaries were adjusted up or down to coincide with faunally inferred time boundaries; many of the boundaries were not mappable (Brown, 1959). The base of the Missourian Series did not correspond to the rock stratigraphic base of the Canyon Group, but was defined by the first occurrence of Missourian fossils including fusulinids of the genus *Triticites*. The Home Creek Limestone was, however, accepted by Cheney as the top of the Missourian Series, based on the first occurrence of Virgilian fusulinids.

Guidebooks and articles by the Abilene Geological Society (1954, 1955), North Texas Geological Society (1940, 1956, 1958) and West Texas Geological Society (1951) have contributed to the knowledge of Canyon stratigraphy. Recent studies include those of Eargle (1960), Terriere (1960), Laury (1962), Feray and Brooks (1966), Brooks and Bretsky (1966), Feray and Jenkins (1953) and Bretsky (1966). Perkins (1964) mapped the Canyon Group of south-central Jack County; Raish (1964) described and interpreted the petrology of the Chico Ridge Limestone in western Wise County; and Pollard (1970) investigated the Winchell Limestone near Lake Possum Kingdom (northwestern Palo Pinto County), with emphasis on the role of phylloid algae in carbonate bank evolution. Heuer (1973) studied paleoecologic relationships in the Wolf Mountain Shale of the Lake Possum Kingdom area. Significant lithofacies studies of the Canyon Group were completed by Wermund (1966, 1969), Wermund and Jenkins (1968, 1969, 1970) and Brown and Goodson (1972).

TECTONIC SETTING

During Missourian time (Fig. 3) prominent mountainous uplands of the area included the Ouachita Fold Belt on the east and the Amarillo-Wichita-Arbuckle Mountains to the north. To the south, the Llano Uplift may have stood as a group of intermittently emergent islands of modest relief. The Matador Arch - Red River Uplift - Muenster Arch system extended across North Texas in a series of local, structurally high areas underlain by buried granitic basement. The Red River Uplift of northern Clay, Wichita and central Wilbarger counties was the site of a stable carbonate platform during Missourian time; the east-west arch system persisted primarily as a result of stability and nonsubsidence of its granite core rather than to anticlinal uplift (Wilson, 1952).

The Bend Arch extended northward from the Llano Uplift in the form of a broad northward plunging flexure. Cheney (1929) considered the Bend Arch to be a hinge between the Fort Worth and Midland Basins (Fig. 3). During Late Mississippian and Early Pennsylvanian times, the Fort Worth Basin subsided as a foreland basin along the western margin of the Ouachita Fold Belt. During Middle Pennsylvanian time, the eastern flank of the Fort Worth Basin began to rise, the Midland Basin began to subside more rapidly and the Bend Arch originated as a hinge between the two depressed basin areas. Thick terrigenous clastic deposits of the Atoka and Strawn Groups essentially filled the Fort Worth Basin by the beginning of Missourian time, except for structurally low areas in northern Montague, Clay and Wichita counties.

The Eastern Shelf, a Pennsylvanian/Permian physiographic feature on the structurally stable eastern flank of the Midland Basin,

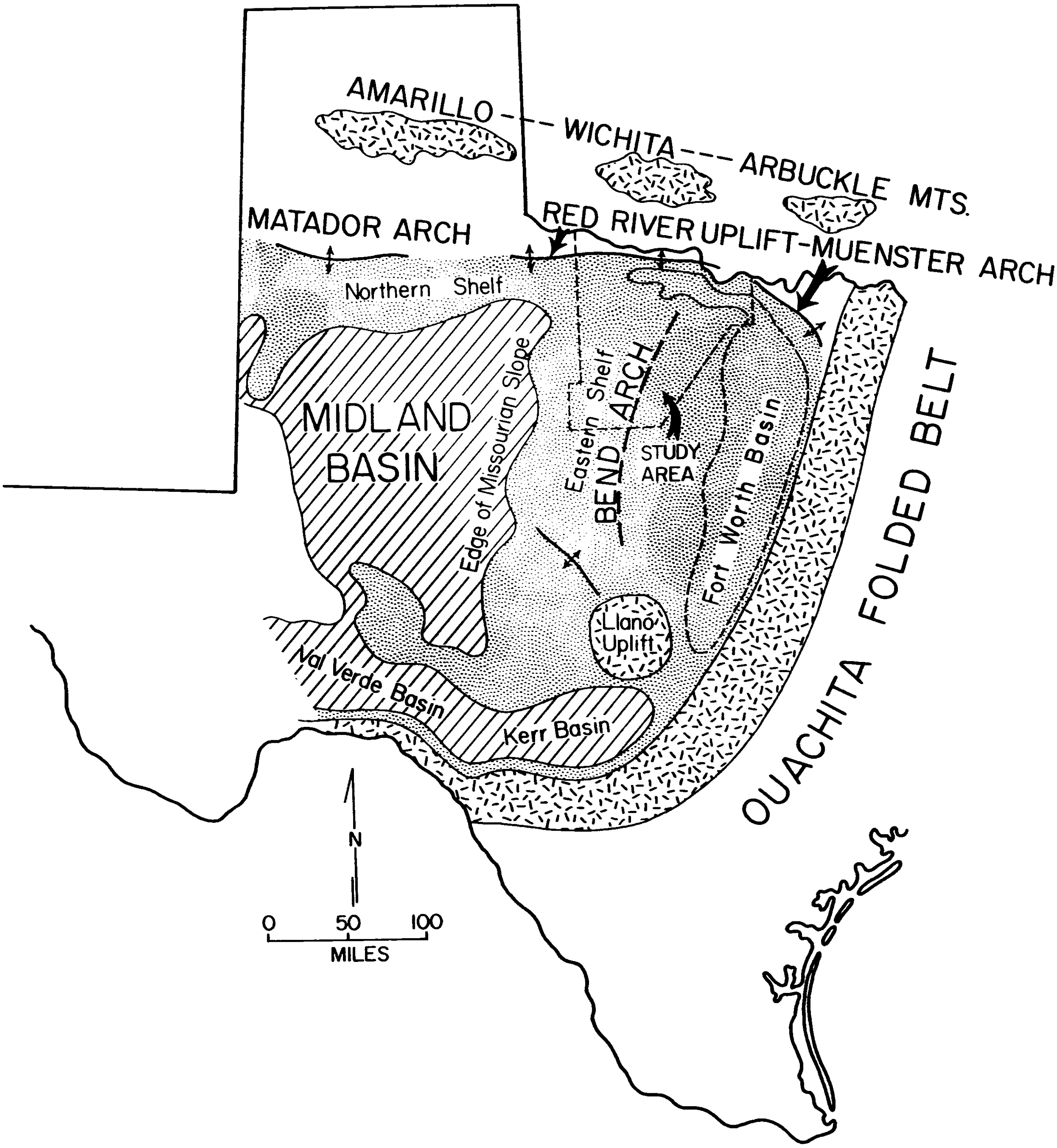


Figure 3. Tectonic setting for North-Central Texas during the Missourian Epoch (Modified from Wermund and Jenkins, 1969).

was a broad, relatively flat homocline, which sloped gently to the west and northwest during Missourian and Virgilian times. The Eastern Shelf developed as a stable structural element on the older Concho Platform, a positive structural feature in North and West-Central Texas during the early and middle Paleozoic.

The term Eastern Shelf, as used in this report, refers to the tectonically stable margin of the Midland Basin and is not synonymous with the term "continental shelf." The term shelf, when used independently, refers to a zone extending from low waterline to the depth at which a marked increase in slope occurs, termed the shelf edge (Galloway, 1970). Shelf deposition, as used herein, refers to deposition (such as carbonate accumulation), which was in equilibrium with existing shelf processes and conditions. As an example of this usage, a variety of sedimentary facies, including fluvial and deltaic sandstone and coal beds, were deposited on the physiographic, structurally stable Eastern Shelf, but only carbonate and mudstone units were deposited within the shelf depositional environments seaward of the deltaic systems.

Steep dips through Nolan, Taylor, Jones, Stonewall and King counties (Fig. 4) mark a westward-facing Missourian shelf edge that flanked the deep Midland Basin.

The Ouachita Fold Belt and the Wichita-Arbuckle Mountains supplied terrigenous clastic sediments to the northern part of the Eastern Shelf throughout most of Missourian time. In addition, uplifted clastic rocks of the Atoka and Strawn Groups along the eastern flank of the Fort Worth Basin served as a source of Canyon clastic sediments.

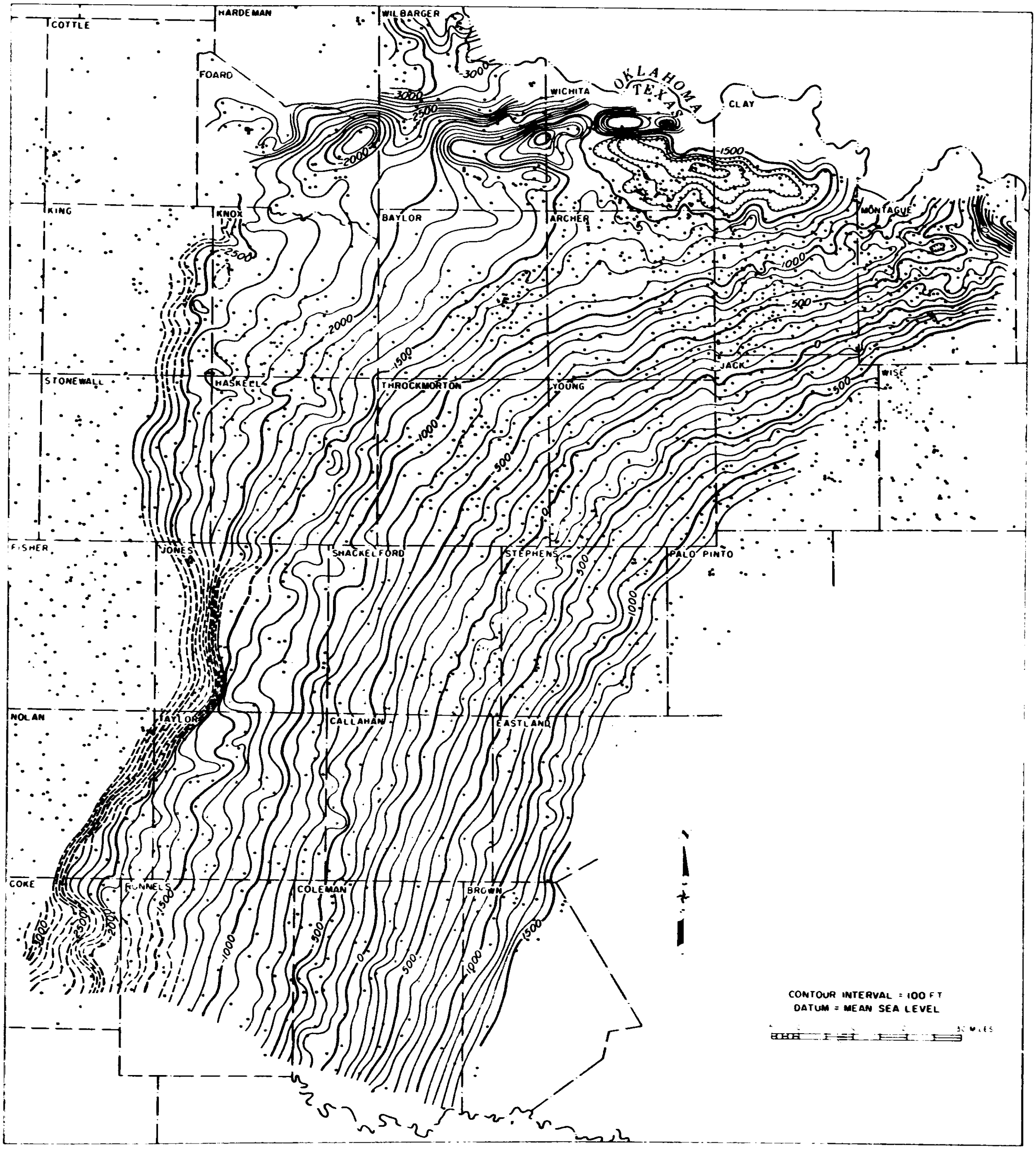


Figure 4. Structure contour map, top of Home Creek Limestone; North-Central Texas (Adopted from Wermund and Jenkins, 1969).

DEPOSITIONAL SYSTEMS

General Relationships

During deposition of the Canyon Group, a variety of depositional systems existed in North and West-Central Texas (Figs. 5 and 6). Complexly interrelated sandstone, conglomerate, shale and limestone facies record these distinctive depositional systems (Plate I).

Thick terrigenous clastic facies of the Canyon Group, which crop out in Jack and Wise Counties, have been referred to informally (Pollard, 1970) as the "Perrin delta complex," after the town of Perrin in southern Jack County. In this report, "Perrin delta system" is used to refer to the thick clastic facies that occur in outcrop and in the subsurface in that region. The Perrin system consists of terrigenous clastic rocks in the Wolf Mountain, Winchell, Placid, and Colony Creek Formations. Perrin delta lobes repeatedly prograded westward and northwestward across Jack, Young, Clay, Archer, Throckmorton and Baylor counties.

Thick wedges of feldspathic sandstone and conglomerate in northern Montague, Clay, Wichita and Archer counties define the Henrietta fan delta system, which built south and southwestward into Texas, supplied by high-gradient fluvial systems that originated in the Wichita-Arbuckle Mountains of Oklahoma.

In addition to terrigenous clastic systems, a variety of carbonate systems have been recognized. These include thick algal-crinoid carbonate bank systems, such as the Winchell and Chico Ridge banks, which were elevated above the surrounding sea floor. As the Perrin delta was abandoned, subsidence by compaction allowed transgressive shelf systems,

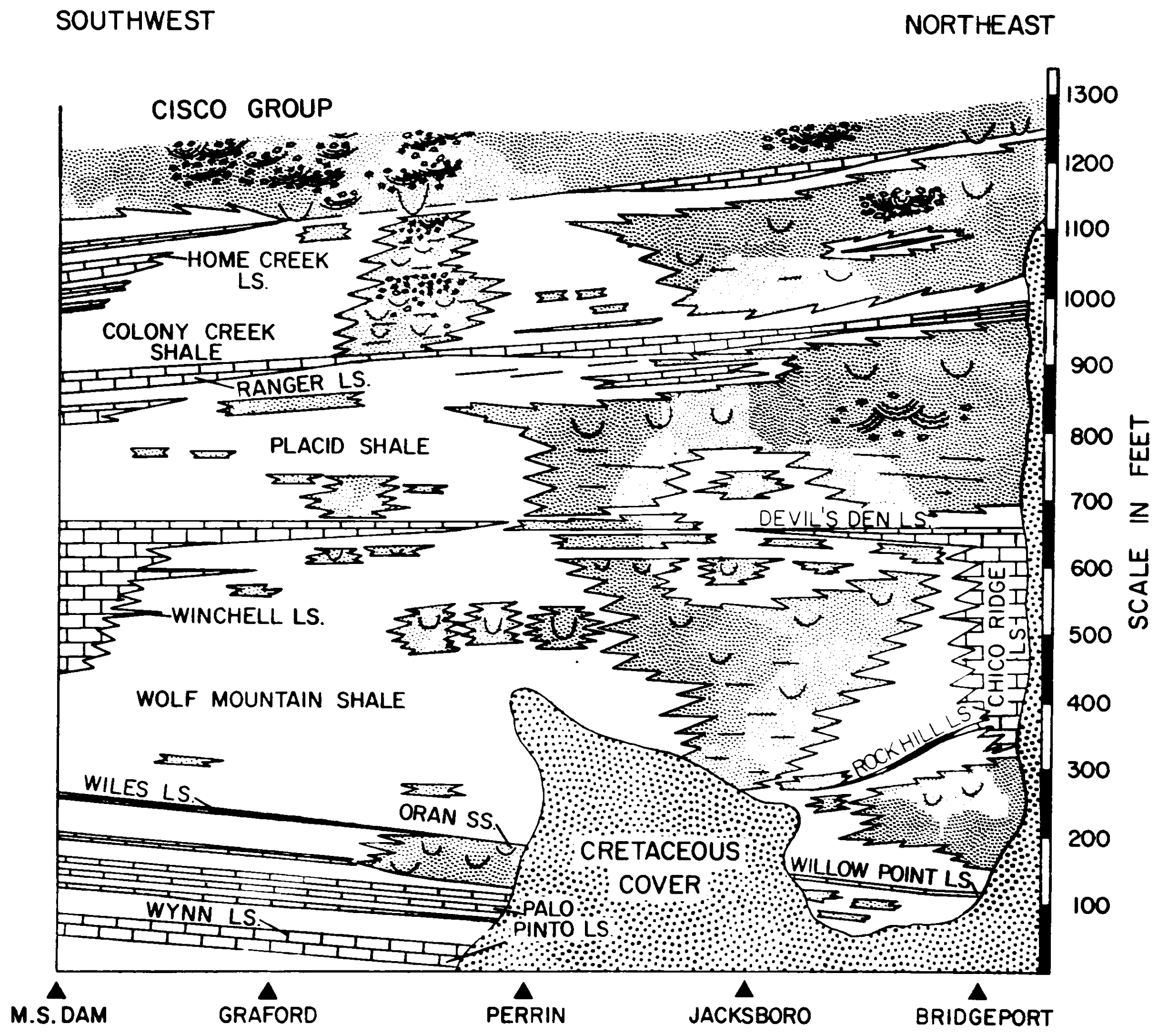


Figure 5. Schematic facies section along outcrop, Canyon Group; northern Palo Pinto, southeastern Jack, and western Wise Counties, Texas; based on 42 measured sections and lithofacies mapping.

composed of relatively thin shelf mud and carbonate facies, such as the Ranger and Home Creek Limestones, to transgress the deltaic platforms.

Other carbonate systems include the Red River carbonate platform, composed of over 2,000 feet of limestone overlying the stable granitic mass of the Red River Uplift. A shelf edge reef-bank system developed along the Canyon shelf edge in Haskell, Jones and Taylor counties. Another thick carbonate accumulation, similar in geometry to the precipitous shelf edge reef-bank accumulations of Haskell County, is located in eastern-central Baylor County. These shelf edge and outer shelf reef-bank systems are thick (up to 1,500 feet), localized carbonate buildups, which are generally not more than 15 miles in length and 8 miles in width.

Wermund et al. (personal communications, 1973) recognized the presence of thick Canyon sandstone units basinward of the reef-bank system in western Haskell, eastern Stonewall and northern Jones counties. These sandstone accumulations are vertically persistent throughout the Canyon Group in that area, and probably represent slope-basin depositional systems similar to those described by Galloway and Brown (1972, 1973) for the overlying Cisco Group. The Perrin delta system, and other deltaic systems, which prograded from the north, supplied sediment to the slope-basin fans. These thick relatively deep-water clastic deposits require further study before their exact geometry and relationships to other Canyon depositional systems can be determined.

Perrin Delta System

The Perrin delta system persisted in eastern Jack and western Wise Counties during Missourian time. Deltaic progradation ceased

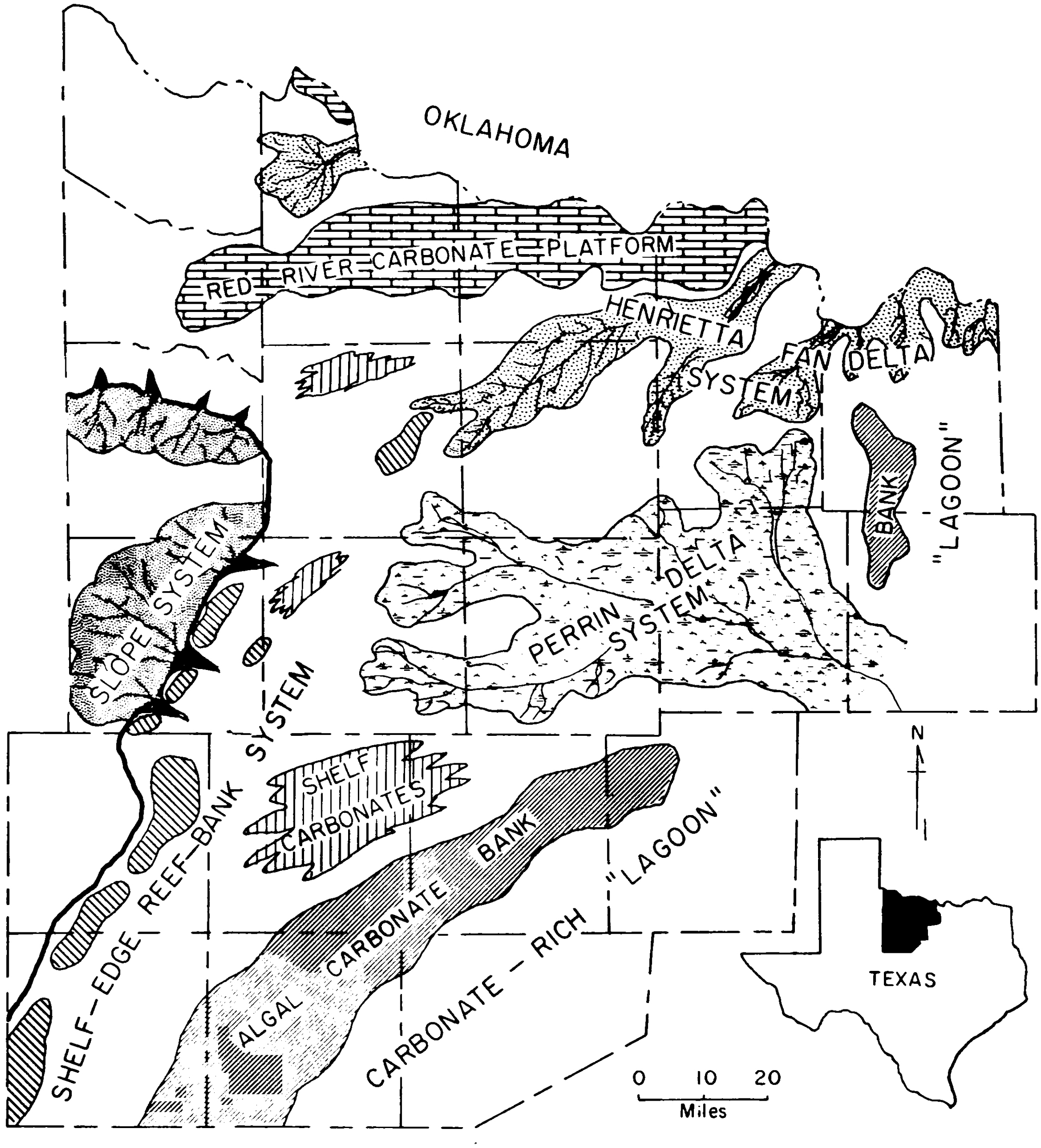


Figure 6. Generalized depositional systems during deposition of the Canyon Group, North-Central Texas.

periodically because of one or more of the following: (1) decreased tectonism in the Ouachita Fold Belt; (2) changing climatic conditions; (3) basinal or eustatic sea level changes; or (4) shifts in the centers of deltaic progradation. Deltaic abandonment and destruction were marked by marine transgressions and deposition of sheet-like shelf carbonates. Three primary intervals of Perrin deltaic deposition include the Wolf Mountain-Winchell Formations, the Placid Formation, and the Colony Creek Formation. Surface and subsurface facies in each of these intervals are considered in sections to follow, but first a short discussion of some modern deltaic facies analogues is in order.

Modern Deltaic Models

Fisher (1968) classified deltas on the basis of marine reservoir energy versus the progradational and aggradational influence of the river system. Deltas composed of a "--large proportion of fluvially influenced (constructive) facies are considered high-constructive systems; systems consisting predominantly of marine influenced (destructive) facies are high-destructive systems" (ibid, p. 48). High-constructive deltas take two basic forms, high-constructive elongate deltas and high-constructive lobate deltas.

Elongate deltas include the modern Mississippi or "birdsfoot" delta and some small bay-head deltas in which the fluvial process dominates over the effects of marine waves, currents and tides; elongate deltas build basinward rapidly by progradation of elongate bar-fingers. Fisk (1961) described the geometry, structures and facies relationships associated with prograding bar-fingers of the Holocene Mississippi

Delta (Fig. 7). Bar-finger sand units are composed primarily of distributary-mouth bar facies. Bar-fingers of the Mississippi Delta comprise elongate sand lenses up to 5 miles in width. Bar-finger sand units may be up to 250 feet thick, due to the highly compactable character of the underlying water-saturated prodelta mud, which allows distributary-mouth bar sands to stack up with virtually complete preservation.

As a distributary channel progrades basinward, its thick channel-mouth bar builds over prodelta clay and silty clay; a zone of delta-front sand, silt, and mud is deposited in front of and lateral to the channel. Prodelta mud, therefore, grades upward into silty sands and well-sorted coarser sands of the channel-mouth bar. The channel-mouth bar is transitional with overlying silty sand and mud of the natural levee deposits; organic-rich peaty clay, representing marsh deposits, may flank the natural levees. Bar-finger sand is fine to very fine grained and contains scattered plant material and thin layers of macerated plant debris. Sands are well laminated and sand and silt laminae are intercalated with laminae composed principally of plant fragments. Thin trough cross stratification occurs throughout and a sparse fauna inhabits the environment.

Bar-finger deposits are interrupted by minor growth faults and contorted beds. Locally, sand and silt are contorted by upward movement of mud diapirs, caused by the excessive loading of water-saturated prodelta muds by thick channel-mouth bar sands. Distributary channels locally cut out upper parts of bar-finger deposits. Distributary channel-fill deposits exhibit medium- to large-scale trough cross stratification, plant debris and some clay pebbles and chips; sands are

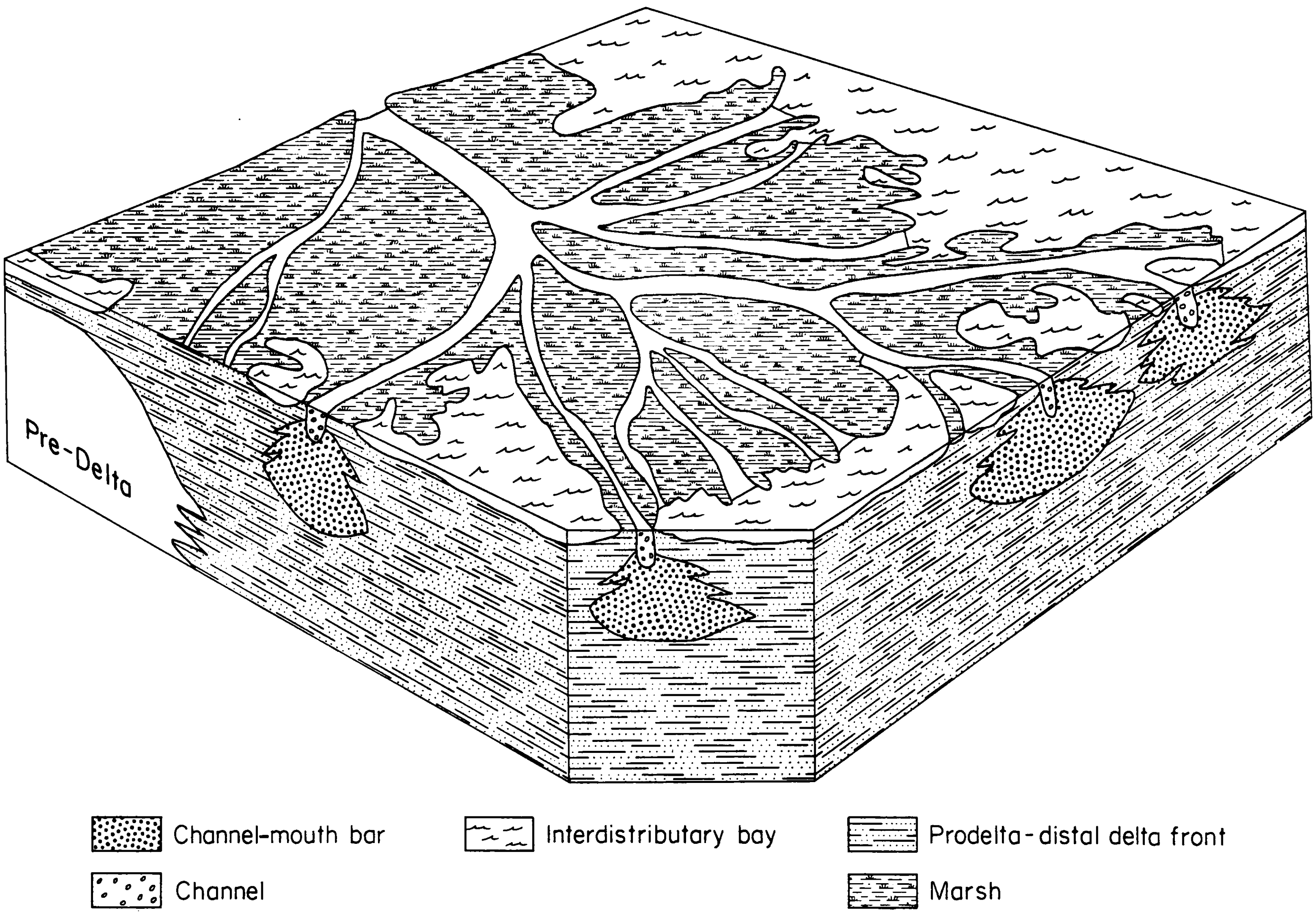


Figure 7. Block diagram of high-constructive elongate birdfoot lobe, modern Mississippi Delta; after Fisk and others (1961).

fine-grained and are generally well sorted.

Lobate deltas, such as the abandoned St. Bernard, Lafourche and Teche lobes of the Holocene Mississippi Delta, display fan-shaped to lobate geometry. Marine processes redistribute fluvial sands into sheetlike delta-front facies (Fig. 8) with localized sand accumulations near distributary mouths (Frazier, 1967). Lobate deltas contain less mud than elongate deltas; consequently, with thinner prodelta facies, the foundering of abandoned deltaic lobes is relatively slow. Marine processes significantly rework and redistribute distal parts of lobate deltas (Fisher et al., 1969).

Prodelta mud units are laminated, whereas delta-front silty sands tend to display small-scale ripple cross stratification. Delta plain mud is organic-rich and may be root mottled and contain abundant wood fragments. Individual lobate delta lobes develop, according to Frazier (1967), in four basic steps. Distributaries begin their initial progradation into the marine environment, and as the system enlarges by further progradation, delta-front silty sands are worked laterally into sheet-like deposits, while delta-plain peat and inorganic mud of the natural levees accumulate. New distributaries form by crevassing, by avulsion of the main stream, and by bifurcation of pre-existing distributaries. Distributary channels locally erode distributary mouth bars during periods of high discharge. As distributaries are abandoned, delta-plain and delta-front sediments subside and may eventually be reworked by marine processes. Delta-margin islands form from reworked deltaic sand; oyster reefs may occupy newly formed lagoons and embayments. Old distributary courses may be reoccupied or new distributaries may form over the old subsided deltaic complex.

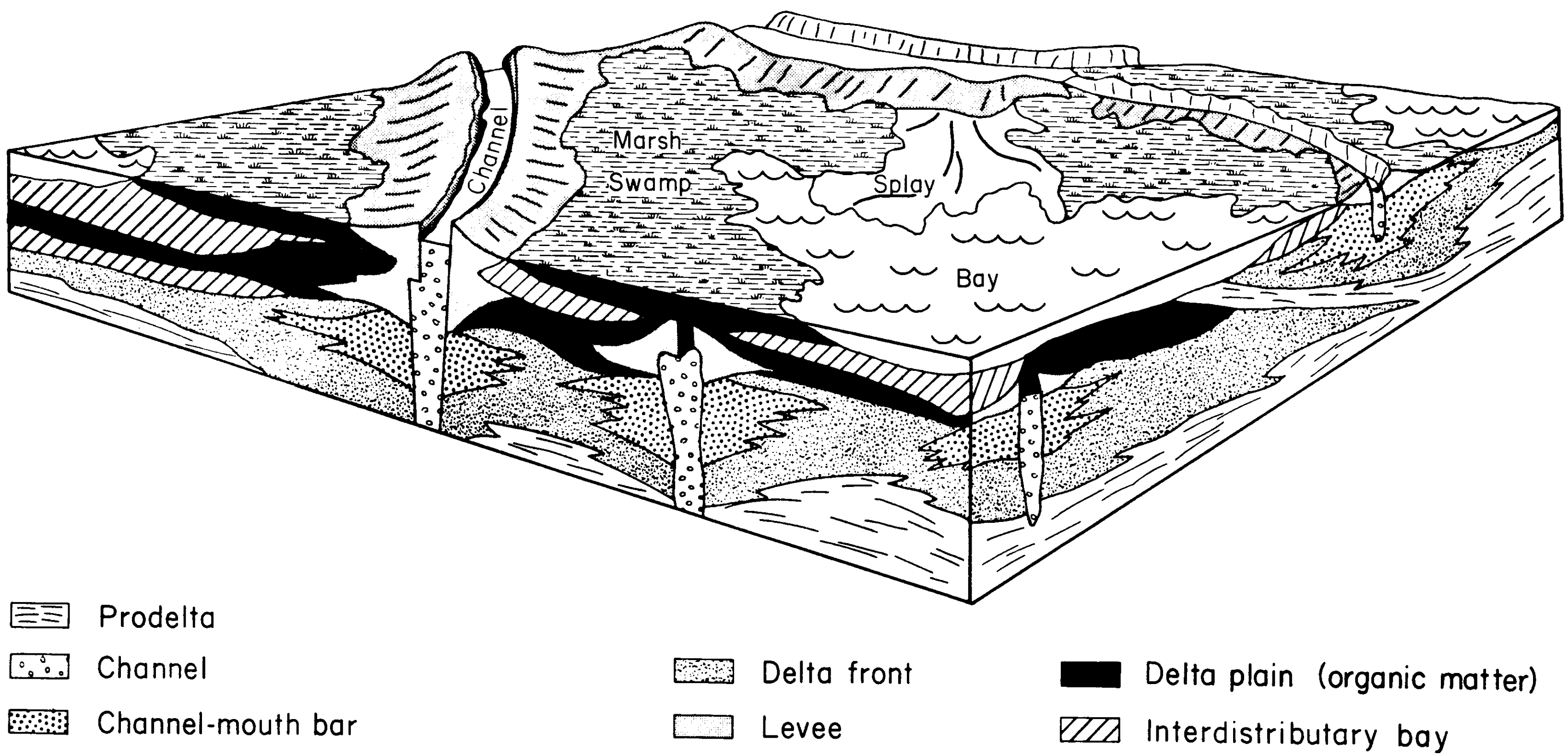


Figure 8. Block diagram of a high-constructive lobate delta, Lafourche lobe, Mississippi Delta (after Frazier, 1967).

Deltaic lobes build seaward until they become overextended (Scruton, 1960). The river then shifts by avulsion to a shorter route to the sea; the old delta lobe is abandoned, and the sediment supply is shut off. Sand may be widely distributed over broad areas of the foundering deltaic lobe as thin, highly bioturbated sheet-sand facies.

Commonly-preserved modern delta plain facies include (Kolb and Van Lopik, 1966): (1) marsh deposits composed of peat, organic-rich mud and flood-borne silt and clay; (2) abandoned tidal channels filled with fine, well-sorted silt and clay containing some detrital organic matter; (3) lake deposits composed of fine clay and organic colloids showing no trace of bedding; (4) swamp deposits containing logs, in-place stumps and root systems, and plastic clay with local peat and layers of decayed wood. Natural levee deposits are composed of mud and sandy mud.

Elongate and lobate lobes of the Mississippi Delta were and are deposited by high-constructive deltaic processes. Certainly, the scale and relative proportions of sedimentary facies, are different for every delta, whether modern or ancient. Facies relationships and sand geometry in the Perrin delta system, however, indicate high-constructive lobate and elongate delta deposition, similar to the Holocene and modern Mississippi system.

Perrin Delta Facies

Within the outcrop area (Plate I), stratigraphic and facies relationships exhibited by the delta system were determined from measured sections (Plates II, III; Appendix 1). An idealized sequence of deltaic constructional and superposed destructional and open shelf facies was recognized (Fig. 9). Coarsening-upward constructional facies record a prograding delta; marine-reworked destructional facies record delta abandonment, marine transgression caused by compaction of prodelta mud, and redistribution of deltaic sediments by marine processes. As subsidence progressed, fossiliferous open-shelf mud, overlapped by carbonate, transgressed abandoned delta lobes.

Prodelta Facies.--Prodelta mudstone facies of the Perrin system are similar to Mississippi prodelta muds. For example, Perrin prodelta and superjacent distal delta-front facies commonly are well laminated with alternating silt and clay laminae, and contain abundant reddish ferruginous (oxidized) claystone nodules and fine macerated plant debris. Prodelta facies are generally dark gray to black, but local reddish to purplish zones are also present. Invertebrate fossils are rare to absent in most Perrin prodelta mudstones; distal prodelta facies may locally contain invertebrate fossils, especially mollusks. Distal prodelta mudstone units may also contain conularids. Prodelta facies were deposited by suspension deposition, to give laminated siltstone and claystone; prodelta mud is locally bioturbated.

Prodelta facies, which were deposited by numerous lobes of the Perrin delta, may range in thickness from 3 to 4 feet in minor lobes up to 200-300 feet in major lobes of the Wolf Mountain Formation. In outcrop, prodelta facies underlie delta-front and distributary channel-fill sandstone facies and may overlie and grade laterally into highly fossiliferous open-shelf mudstone and carbonate units.

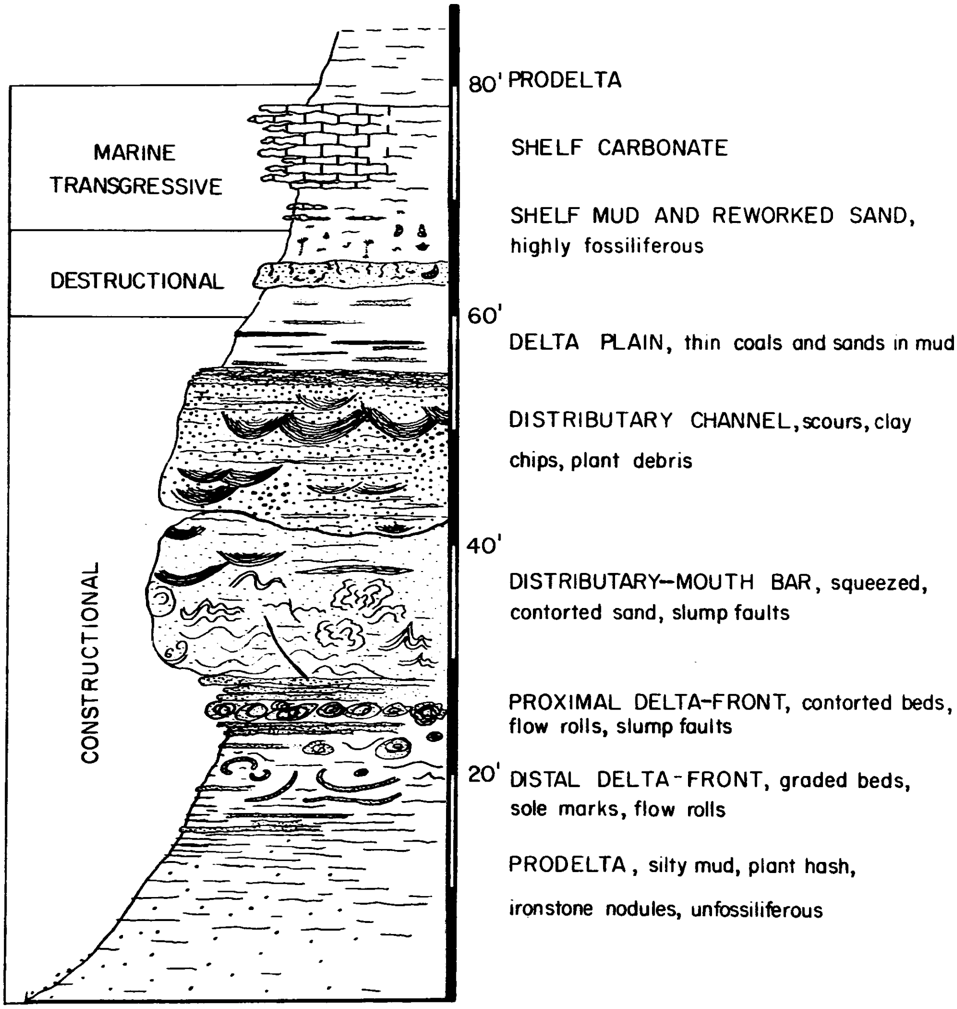


Figure 9. Idealized delta sequence, Canyon Group, North-Central Texas.

Distal Delta-Front Facies.--Prodelta facies grade into very fine-grained sandstone and siltstone laminae of overlying distal delta-front facies. Thin, distal delta-front sandstone beds (generally less than 1 foot thick) are rich in fine, black plant debris and locally exhibit rippled bedforms on upper surfaces. Load casts, flute casts and horizontal feeding trails are common on undersurfaces of thin, flaggy, distal delta-front sandstone beds. Sandstone beds are commonly graded and locally show small-scale trough cross stratification. Horizontal laminae, however, are the most common sedimentary structures. Thin distal delta-front sandstone beds were probably deposited by local turbidity currents generated by high flood waters debouching through distributaries. Flood surges eroded distributary-mouth bar and delta-front facies; resulting turbidity currents redeposited the sand in thin, distal delta-front sedimentation units. Sandstone beds commonly were rolled and contorted by contemporaneous slumping into water-saturated prodelta muds. Distal delta-front facies are virtually unfossiliferous because of the rapid influx of sediment and generally unstable nature of the sediment-water interface. These facies are from a few feet to a few tens of feet thick and are gradational with overlying and underlying sediments.

Proximal Delta-Front Facies.--Proximal delta-front sandstone facies of the outcropping Perrin delta are fine to very fine-grained, well sorted quartzarenites. Commonly, the facies is thin to thick bedded and is gradational with underlying distal delta-front units. Sedimentary structures include abundant horizontal laminae and locally concentrated trough cross stratification; locally current ripple bedforms are preserved on upper bedding surfaces (Fig. 10). The sandstone beds are commonly contorted and rolled, especially near their bases, and may exhibit growth faults and a variety of load features. Proximal delta-front sandstone units normally contain abundant plant debris ranging from macerated "coffee grounds" to stems and leaves a foot or more in length. Bedding surfaces are normally covered with black flecks of fine plant fragments. Proximal delta-front sandstone units, which display a sheet-like distribution, can extend laterally for several miles and interfinger with shelf and interdistributary facies. Delta-front sandstone units of the Canyon Group range from a few feet to 100 feet thick.

Fine-grained, proximal delta-front sandstone beds in southeastern Jack and western Wise Counties (Locality C) commonly weather to massive boulders, which appear squeezed, contorted and rolled. These sandstone beds are invariably rich in plant debris, including whole leaf impressions and *Calamites* pith casts. Concentrations of clay clasts and reddish ferrugenous claystone nodules are common. The sandstone beds may also contain abundant fine clay chips. Burrowing is generally restricted to the upper parts of proximal delta-front sandstone sequences and as local horizontal feeding trails on bedding surfaces.

Thick sandstone units of *distributary-mouth bar* origin may contain abundant trough cross stratification as well as a variety of sandstone lenses, growth faults and load phenomena (Figs. 10 and 11). These relatively thick bar accumulations are normally contorted, especially near the bases, as a result of the rapid, local deposition of sand over highly compactable prodelta and distal delta-front mud. They may range from tens to hundreds of feet across and be from 10 to 200 feet thick.

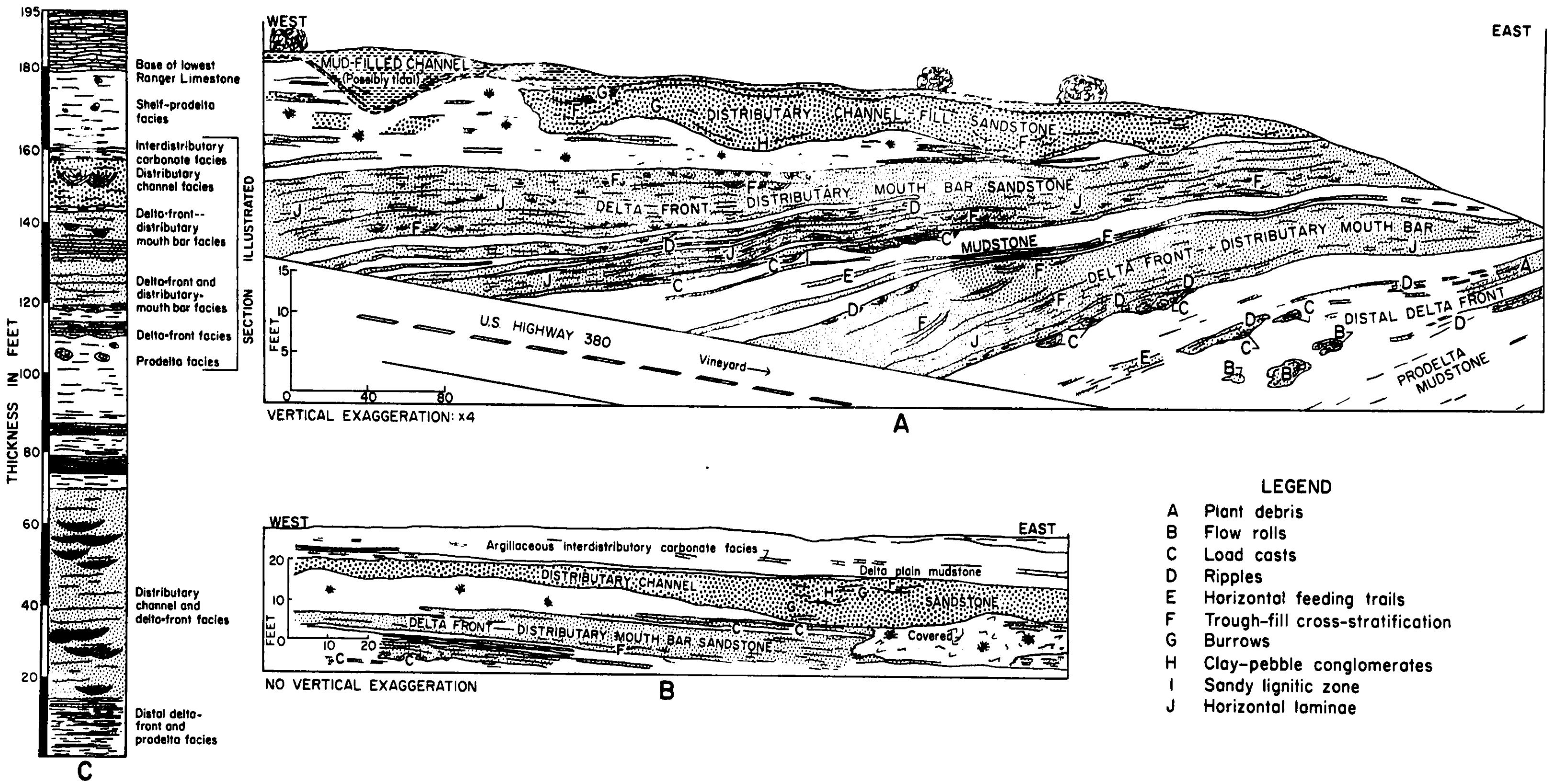


Figure 10. Delta-front and distributary-channel facies, Placid Shale, along U. S. Highway 380, 2.5 miles west of Vineyard in eastern Jack County, Texas; Measured Section I, Plates I and III; A. North side of road showing deltaic facies sequence of a Perrin delta lobe. B. South side of road showing delta-front and superposed distributary-channel-fill sandstones. C. Measured section, upper part of Placid Formation exhibiting deltaic sequences and superposed transgressive facies.

Two and three-tenths miles north of Wizard Wells, Texas (Measured Section 3) fine-grained sandstone units up to 100 feet thick are exposed within the Placid Formation. These sandstone units, which weather to contorted boulders the size of small houses and overlie coarsening-upward prodelta and distal delta-front facies, are interpreted to represent bar-finger facies of a high-constructive elongate lobe of the Perrin delta, which prograded toward the northwest.

A massive, fine-grained distributary-mouth bar/distributary channel sandstone unit caps a hill 2.7 miles west of Perrin, Texas (Measured Section 23). The 40- to 50-foot thick sandstone overlies a 60-foot section of sandy, prodelta mudstone. The barfinger sandstone weathers into boulders, a few of which approach the size of small houses. The entire sandstone body apparently underwent post-depositional slumping; bedding surfaces within the sandstone body dip 20 to 30 degrees toward the south. A thinner sequence of delta-front sandstone beds, which slumped down into the underlying mudstone along a well-defined glide plane, is exposed nearby, along the highway near the base of the section. Penecontemporaneous and post-depositional slumping of proximal delta-front and distributary-mouth bar sandstone was common during Canyon deltaic deposition.

Strongly contorted, proximal delta-front sandstone (lower part of Lake Bridgeport Shale) is present in a roadcut along U.S. Highway 380, northwest of Bridgeport (Locality E). Fine-grained delta-front sand (Fig. 12) was injected into prodelta mud during slumping, resulting in unusually rolled and contorted structures. Sandstone beds slumped toward the east to northeast lateral to a northwestward advancing

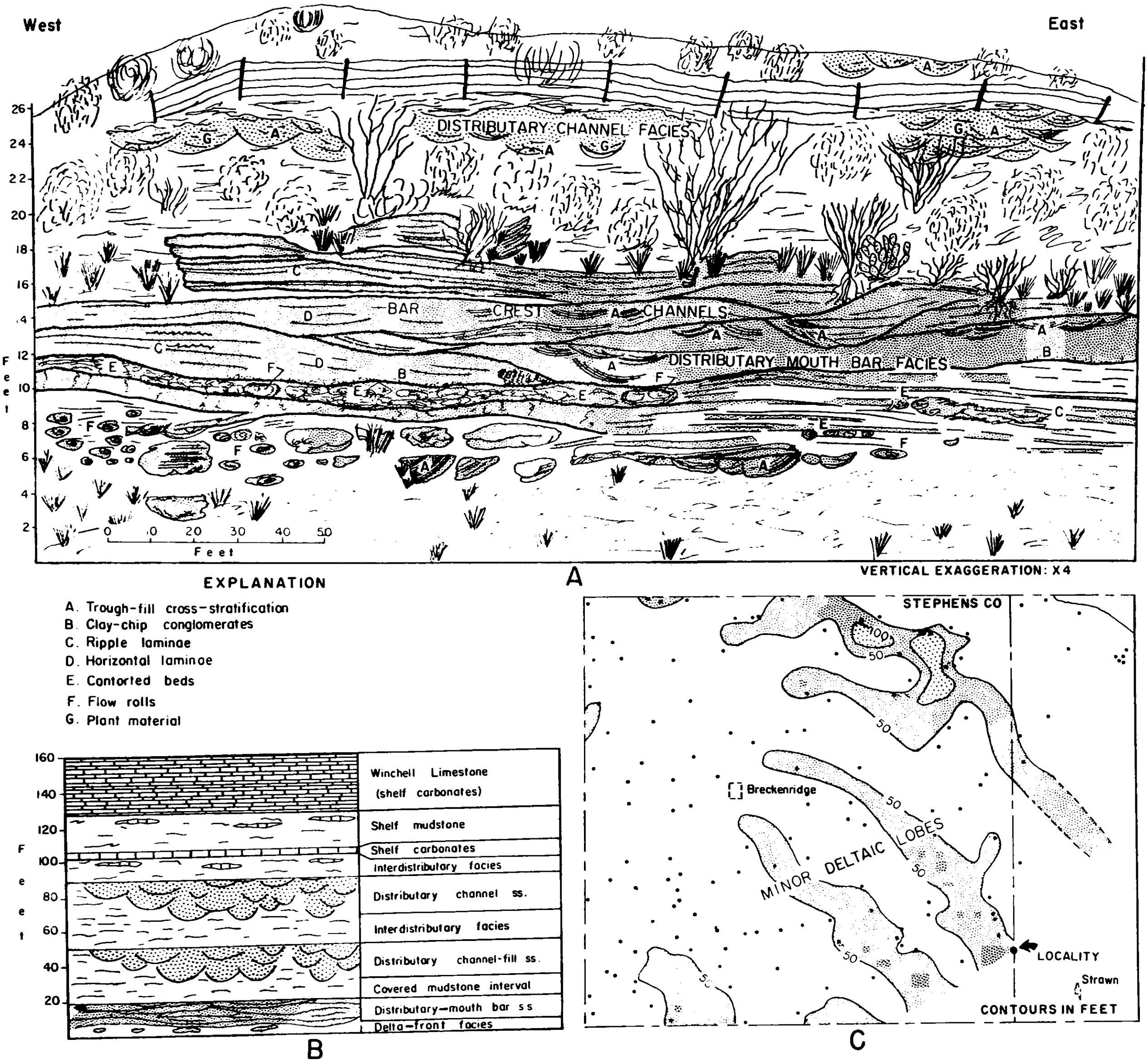
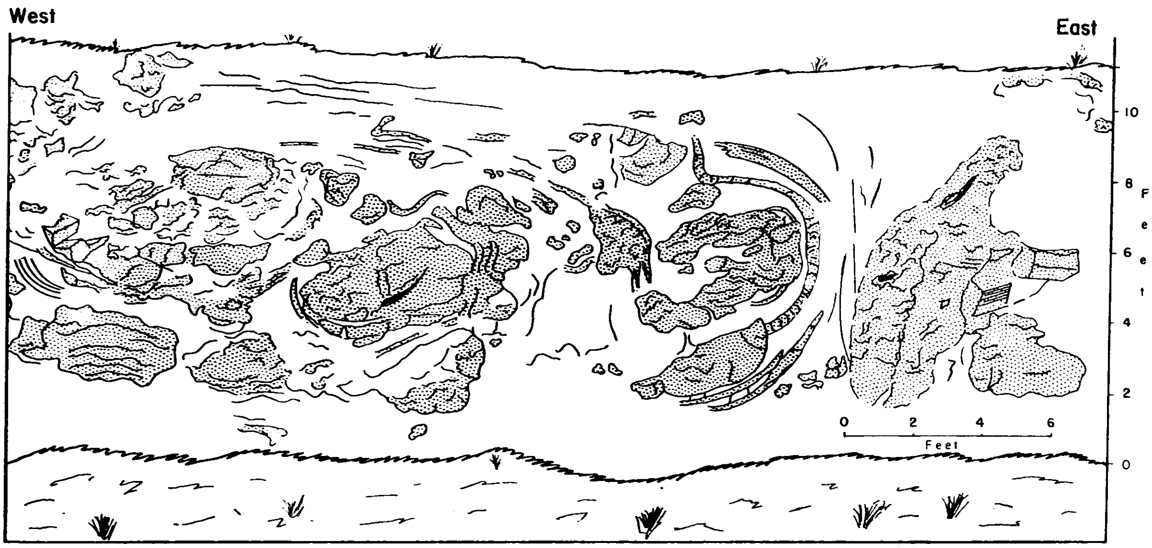


Figure 11. Deltaic sequence in a small delta lobe, Upper Wolf Mountain Shale, along Farm Road 207 at Palo Pinto-Stephens County line; A. Channel-mouth bar facies with superposed distributary-channel-fill deposits. B. Measured section showing deltaic and overlying shelf-carbonate facies. C. Net sandstone thickness map for Wolf Mountain Formation in the area, showing extent of deltaic lobes.



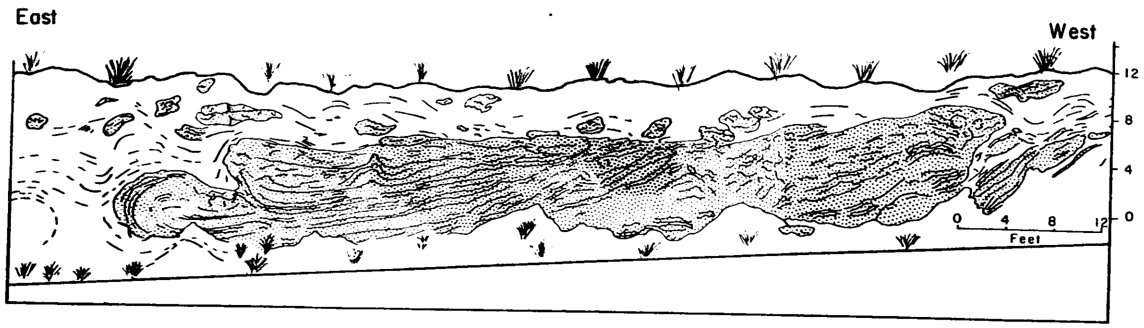


Figure 12. Slumped and contorted delta-front sandstones, Lake Bridgeport Shale (lower part of Wolf Mountain Formation), U. S. Highway 380 near Bridgeport, Texas; Locality E, Plate I; top view, north side of highway; bottom view, south side of highway.

distributary. Net sandstone maps (discussed later) show that the Perrin delta lobes in the area prograded toward the west and northwest.

Distributary Channel Facies.--Fine- to medium-grained, sandstone bodies of probable distributary channel-fill origin normally cut underlying delta-front sandstone and mudstone (Fig. 10 and Locality A). Distributary channel-fill sandstone units are massive, and homogeneous to strongly trough cross bedded and are commonly coarser-grained than underlying delta-front facies. The channel-fill may contain local clay-pebble conglomerate and concentrations of plant stems (particularly Calamites) and leaves up to one foot or more in length, as well as abundant fine plant debris. Distributary channel-fill facies are poorly sorted and contain a high percentage of fine clay particles. These sandstone units generally contain more large plant stems and leaf impressions than do well-sorted quartzarenite varieties (Fig. 11). In outcrop, distributary channel-fill deposits commonly are massive and appear to contain few sedimentary structures. Close examination of distributary channel sandstone units, however, reveals the presence of broad, low-angle trough cross stratification. Although distributary channel-fill deposits may be up to 40 feet thick, they commonly are no more than 8 to 15 feet thick. Some massive distributary channel-fill facies contain small growth faults. Broad sandstone "lenses" must have stood up as depositionally high bar crests or middle ground shoals (Fig. 13).

Bases of distributary channel-fill units are sharp, erosional contacts. Distributary channels commonly overlie progradational, coarsening-upward sequences, but channels also commonly eroded into

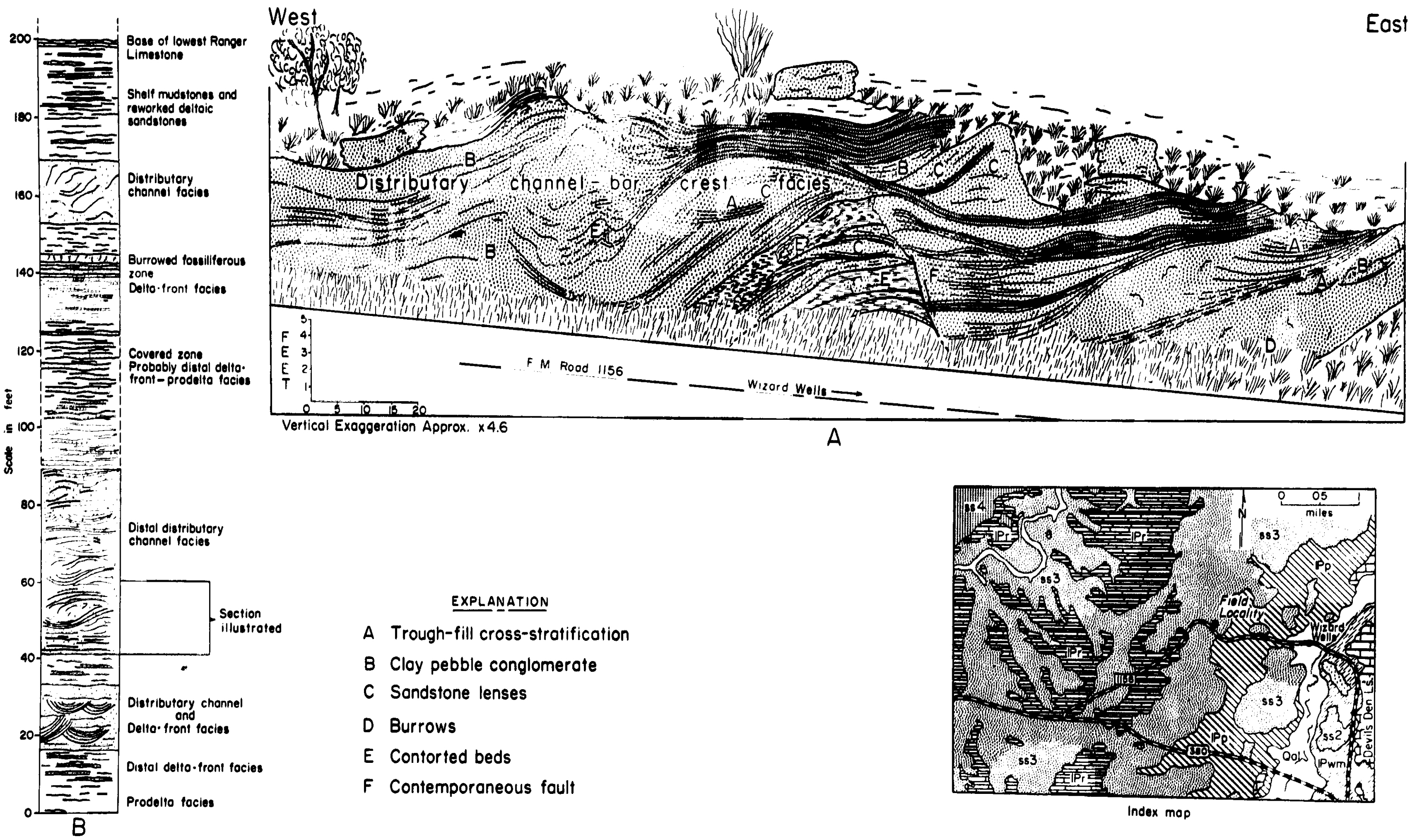


Figure 13. Distal distributary-channel and bar-crest facies, Upper Placid Shale, along Farm Road 1156, 1.4 miles west of Wizard Wells in eastern Jack County, Texas; Measured Section 2, Plates I and III; A. Complex distributary-channel-fill deposits, displaying compactional features. B. Measured section, Upper Placid Formation, showing Perrin facies overlain by shelf mudstones and carbonates.

subjacent interdistributary muds, and now display sharp basal contacts. In these latter instances, distributary channels must have shifted by avulsion and new channels were eroded into older deltaic sediments.

Laminated fine silt, clay and coal locally fill channel-shaped scours in the upper parts of distributary channel sandstone units (Fig. 14). These channel-fill mudstones and coals may represent later reoccupation of the channels and subsequent deposition of fine sediment from suspension after final abandonment. Some of these mud-filled channels may have had a partial tidal origin.

Upper parts of distributary channel-fill and delta-front sandstone facies locally exhibit well developed, straight-crested oscillation ripples and various interference ripple bedforms on upper bedding surfaces; these bedforms probably resulted from marine reworking after delta abandonment. These same sandstone beds are locally burrowed, also indicating occupation of the abandoned delta-front by marine organisms.

Delta Plain Facies.--Facies interpreted to be of purely delta plain origin are rare in outcropping Canyon rocks. Although Perrin deltaic sandstone facies generally contain abundant plant debris, carbonaceous clay and coal are rare. A possible explanation is that subsidence was slow on the tectonically stable Eastern Shelf and, therefore, thick delta plain deposits did not develop as they have done within rapidly subsiding Mississippi River delta lobes. Marine waves, currents and organisms also would have had ample opportunity to rework and destroy thin, highly organic Perrin delta plain deposits after delta abandonment. Reworked deltaic sandstone beds overlain by highly fossiliferous shelf

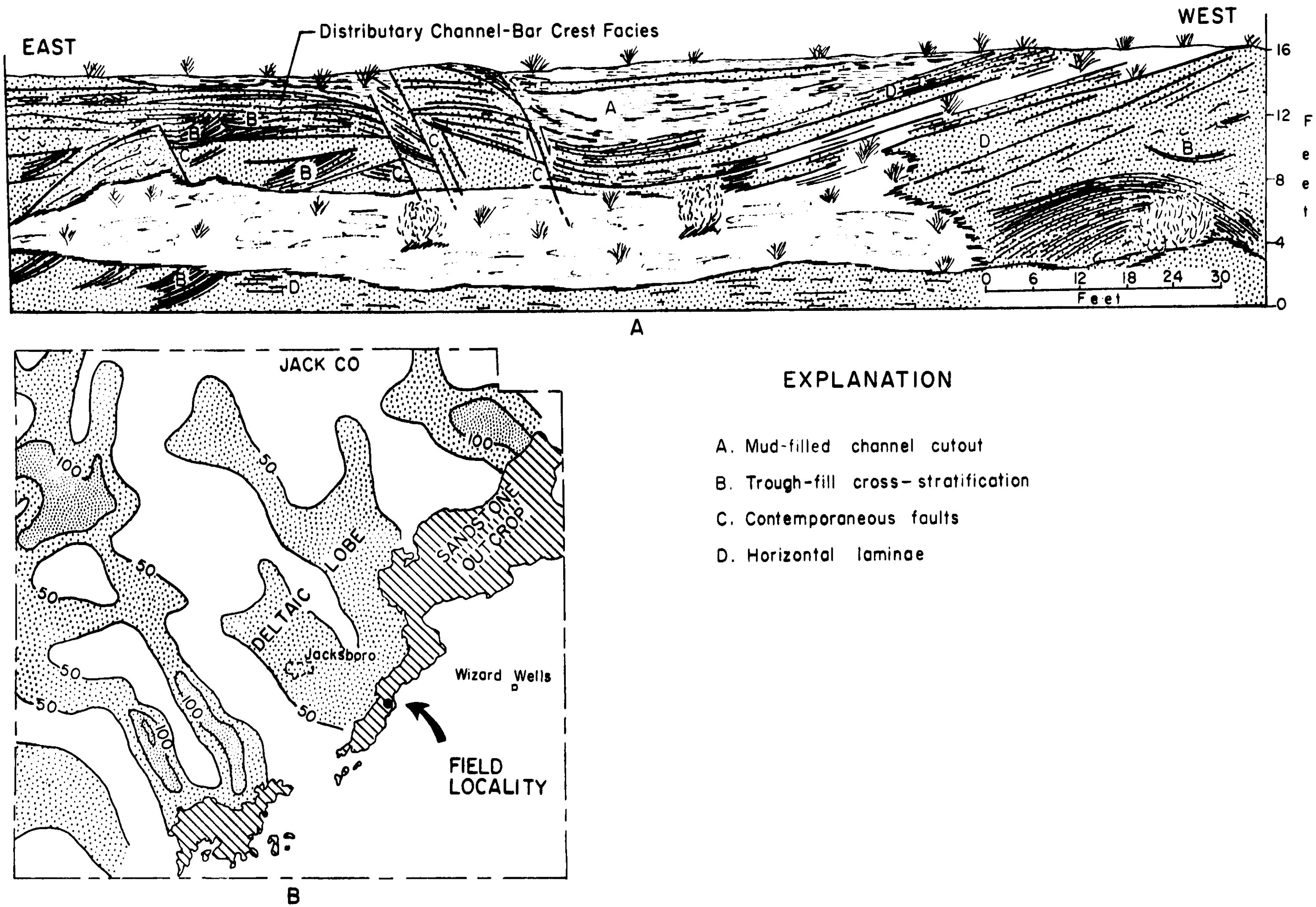


Figure 14. Distributary-channel-fill facies, Colony Creek Formation, south side of U. S. Highway 380, east of Jacksboro, Texas; Locality J, Plate I; A. Distributary-channel-fill facies showing compactional features and mud-filled channel. B. Net-sandstone map of Colony Creek Formation showing extent of deltaic lobes and locality of roadcut.

mudstone units commonly rest directly on abandoned distributary and delta-front facies.

A local coal (Dalton coal), approximately 8 feet thick, crops out in the Wolf Mountain Formation of northwestern Palo Pinto County, approximately 7.5 miles southwest of the town of Graford (Plate I). The coal is a loose, flaky, poorly indurated detrital deposit. The material appears to not have been deposited in place, as no root systems or in-place stumps or stems have been found. The coal rests directly on a one-foot bed of well-sorted and indurated biosparite, which in turn overlies a mudstone that is rich in marine invertebrate fossils. Lateral to and overlying the Dalton coal are sandstone beds, which are interpreted to be of delta-front and distributary channel-fill origin. The underlying biosparite bed may represent a well-winnowed beach, spit, or upper shoreface deposit within a shallow embayment, which formed over fossiliferous interdistributary bay-lagoon mud. Plant debris composing the coal was apparently transported and deposited at the head of a small bay or lagoon located between minor deltaic distributaries.

Another Canyon coal deposit (Bridgeport Coal of western Wise and eastern Jack counties) lies between members of the Palo Pinto Limestone. Scott and Armstrong (1932) reported that the coal is 18 to 22 inches thick and is of good quality. It underlies a 55-foot thick black shale, which contains local sandstone bodies; the Willow Point Limestone, the uppermost Palo Pinto Limestone member of western Wise County, overlies the black shale. Underlying the Bridgeport coal bed is a 20-foot section of blue to black clay that rests on a 12-foot coarse-grained sandstone, which pinches out toward the southwest along strike. Scott and Armstrong stated that plant fossils occur in the Bridgeport Coal, but that they are rare. The Bridgeport Coal extends southwestward to the vicinity of Perrin in southern Jack County (Plate I). The Bridgeport Coal may be an _in situ_ delta plain deposit on a minor delta lobe, which prograded westward through the area. The sub-bituminous nature sets the Bridgeport Coal apart from other detrital coals of the Canyon Group.

Thin, homogeneous mudstone sequences above and lateral to distributary channel-fill facies (Fig. 10) are probably delta plain accumulations in which very little organic material was preserved. These mudstone beds commonly are light gray to tan or brown, as opposed to thick prodelta mudstone units, which are normally gray to black. Plant roots may have destroyed the bedding within many of these inferred delta plain facies.

Fluvial Facies.--Fluvial channels filled with coarse clastic sediments locally eroded underlying Perrin deltaic facies. In the Placid Formation (near the vicinity of Big Creek; Measured Section 7) local channels, which are filled with coarse-grained sandstone and chert-pebble conglomerate, replace underlying fine-grained deltaic sandstone and mudstone facies. These coarse-grained clastic units contain medium- to large-scale trough cross stratification. Individual channel-fill bodies are 10 to 20 feet thick. Because the units are poorly exposed, it is difficult to determine the precise nature of the fluvial system. The coarse-grained facies do not fine upward in grain size or display an upward decrease in scale; they may represent a variety of braided or perhaps coarse-grained meanderbelt system.

In southern Jack County, north and west of Barton's Chapel (Plate I), deltaic sandstone and mudstone units in the Colony Creek Formation (Measured Section 29) are overlain by extensive coarse-grained sandstone and chert-pebble conglomerate. These coarse, channel-fill deposits represent component facies within a coarse-grained fluvial system. The system overrode and locally eroded the underlying, abandoned deltaic sediments.

Thick, widespread channels filled with coarse-grained sandstone and conglomerate locally eroded into the Home Creek Limestone in southwestern Jack, southeastern Young and northwestern Palo Pinto counties (Lee et al., 1938). The lower part of the Cisco Group in this area consists of thick, coarse-grained sandstone, conglomerate and shale facies; only local thin carbonate stratigraphic markers occur within the thick clastic sequence. The area was a site of braided to coarse-grained meanderbelt fluvial deposition during a long segment of Late Missourian and Early Virgilian time.

At the outcrop, coarse-grained fluvial sandstone and chert-pebble conglomerate facies of the Perrin system are similar to coarse fluvial sediments of the underlying Strawn Group. These coarse terrigenous clastics in the Canyon Group may have been derived from Strawn and earlier rocks, which were uplifted and exposed along the western flank of the Ouachita Mountains during Missourian time. Coarse fluvial sandstone and conglomerate facies are not as common in Canyon rocks as they are in underlying Strawn and overlying Cisco Group rocks; the coarse-grained fluvial deposits account for less than 5 percent of the Canyon section exposed in the outcrop study area.

Interdistributary Embayment Facies.--Mudstone interpreted to be of interdistributary embayment origin was deposited between and locally on top of distributary channel-fill and delta-front sandstone. These mudstone units commonly contain abundant but low diversity faunas consisting principally of a few species of pelecypods, gastropods and some crinoids. Thin, argillaceous, fissile to platy limestone beds up to 4 feet thick are associated with the mudstone facies; these limestone units are poorly indurated and are generally tan to brown. Fossils include Composita-type brachiopods, echinoid spines and plates, and small gastropods. Platy algal mats and blades in this facies may comprise a high percentage of the rock. Large amounts of fine, terrigenous silt and clay deposited from overbanking flood waters were mixed with the brackish marine carbonates.

Destructional Facies.--Highly bioturbated, fine-grained sandstone beds interpreted to be of delta-destructional, marine reworked origin commonly overlie Perrin deltaic facies and underlie shelf carbonate facies (Fig. 15). Destructional facies consist of well sorted sand, which was probably reworked by marine waves and currents after deltaic lobes were abandoned. Destructional sandstone beds are generally 2 to 6 feet thick and are commonly extensively burrowed by a variety of vertical, horizontal and branching tubes up to 1 inch in diameter and several inches long (Locality B). Some disarticulated valves of the pelecypod Myalina also occur within the facies. Articulated, apparently in-place, Myalina shells may occur in destructional sandstones, but they are rare. Destructional facies are normally vuggy or spongy, as a result of intense bioturbation. Small-scale trough cross stratification

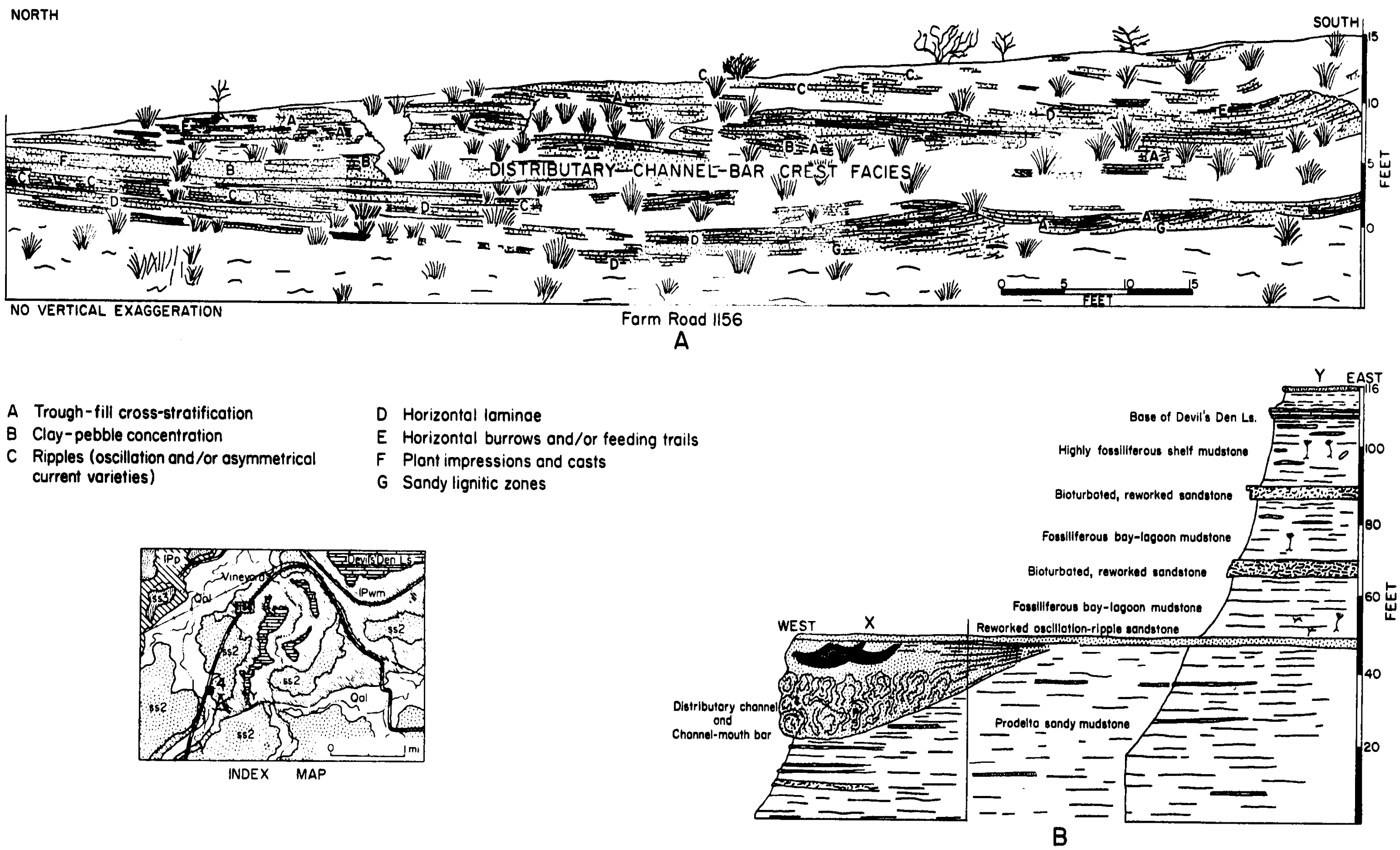


Figure 15. Deltaic, delta-destructional and marine-transgressive facies, upper part of Wolf Mountain Formation along Farm Road 1156 south of Vineyard, eastern Jack County, Texas; Locality H, Plate I; A. Distributary-channel/bar-crest facies in east roadcut. B. Measured sections X(14) and Y(13), Yates Ranch, east of roadcut (Plate I) showing marine-destructional and transgressive facies.

is commonly abundant within the facies. The high porosity and permeability resulting from strong bioturbation, along with calcium carbonate derived from adjacent shelf carbonate units permitted local extensive cementation of destructional sandstones. This facies is commonly gradational between calcareous sandstone and sandy limestone.

Destructional sandstone beds are thin but extensive sheet-like units, which persist for several miles along outcrop. Deltaic facies of the Colony Creek Formation 5 miles east of Jacksboro (Locality B) are overlain by a widespread, 3- to 5-foot thick, highly burrowed, calcareous sandstone facies of delta destructional origin (Plate I). Deltaic sandstone and mudstone below the Devil's Den Limestone (Winchell equivalent) of eastern Jack and western Wise counties (Measured Section 9, 10, 12) are also overlain by thin, reworked, destructional sandstone beds for several miles along depositional strike.

Destructional sandstone of the Perrin system are analogous in position, geometry and sedimentary structures to the transgressive sheet sands and delta-destructional islands overlying the foundering Holocene St. Bernard delta lobe of the modern Mississippi Delta.

Tidal Channel Facies.--Tidal channel-fill deposits are rare in outcrops of Canyon deltaic deposits; only two possible examples have been noted. First (Fig. 10), is a symmetrical channel that was eroded into a massive distributary channel-fill sandstone unit of the Placid Formation. The maximum thickness of the symmetrical channel-fill deposit is 12 to 15 feet and consists of laminated fine siltstone and mudstone. No shell material, burrows or cross stratification have been observed in the channel-fill deposit; the feature may simply be a reoccupation channel in older distributary channel-fill sandstone, and not a tidal channel-fill deposit.

One-half mile east of Brad, Texas, (along Highway 180), within the upper part of the Wolf Mountain Formation, a tidal channel eroded delta plain deposits of a minor delta lobe that was undergoing abandonment and subsidence (Fig. 16). Tidal channel-fill deposits are composed of calcite-cemented claystone pebbles, sand and broken shell debris up to 2 inches in diameter. The deposit contains abundant broken _Myalina_ shells, crinoid debris, brachiopods and various clasts, including ferrugenous claystone nodules; bedding is massive and sedimentary structures are not readily apparent. The upper 4 feet of channel-fill, which is finer than the underlying sediment, consists of well-sorted and indurated biosparite. Overlying the channel is about 15 feet of sandy, mudstone of shallow, open-shelf origin; the Winchell shelf carbonate facies overlies the entire sequence.

Shelf and Interdeltaic Facies.--Highly fossiliferous shelf and interdeltaic mudstone facies overlie and flank Perrin deltaic lobes; these mudstone units are, in turn, overlain by transgressive shelf carbonate facies. The mudstone facies, which have been intensively bioturbated, are locally marly and contain local calcareous lenses and nodules. Invertebrate fossils include a variety of sponges; abundant crinoids and echinoid plates; brachiopods, including productids, chonetids, spirifers, rhynchonellids and rostrospirifers; at least 12 genera of gastropods, (the most common being _Straparolus_); scaphopods (_Dentalium_); several genera of pelecypods; cephalopods, including abundant orthocone nautiloids and several coiled nautiloids and

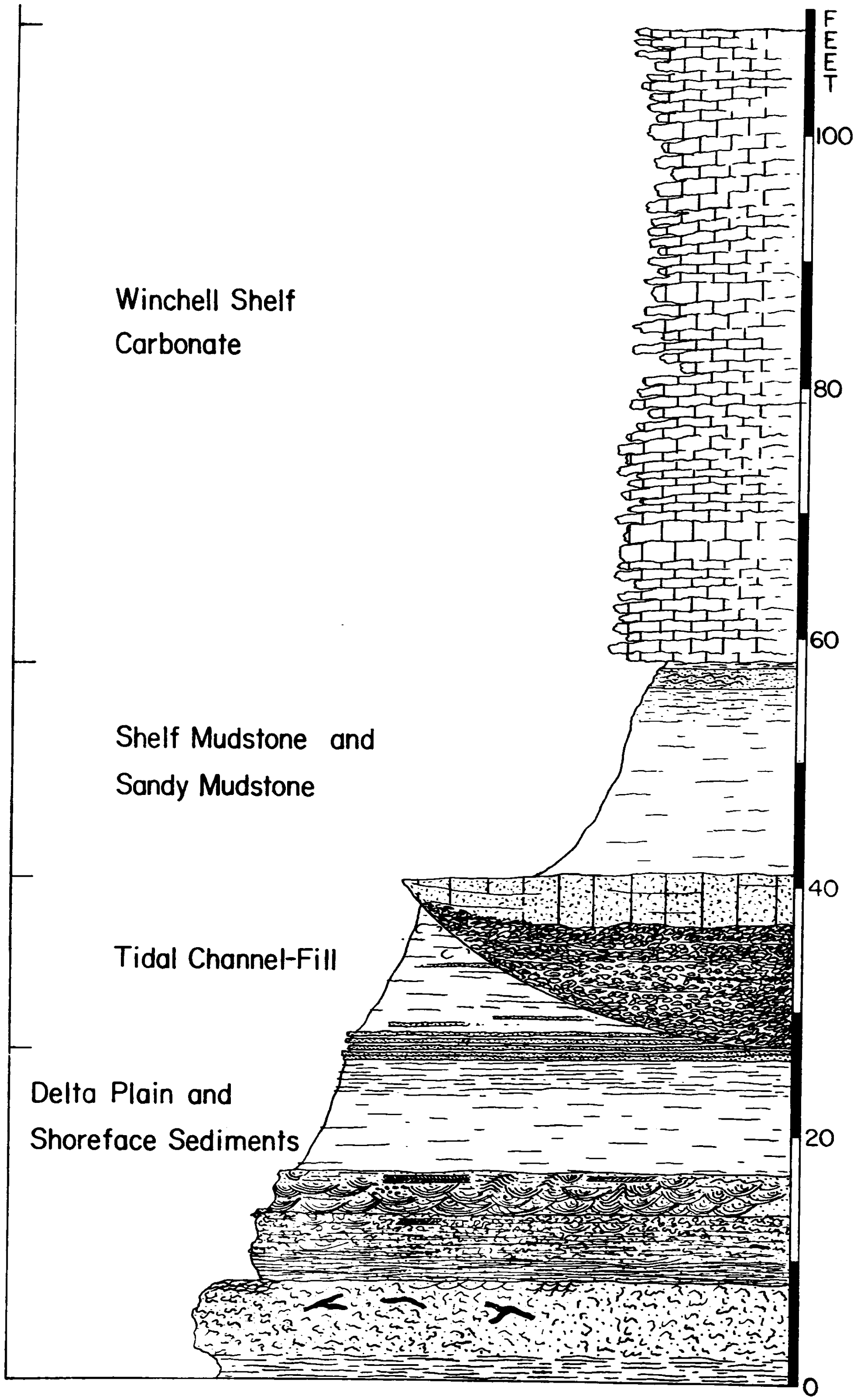


Figure 16. Measured section, upper part of Wolf Mountain Formation, along U. S. Highway 180, 0.5 mile east of Brad, western Palo Pinto County, Texas, showing symmetrical tidal-channel-fill in delta-plain and shoreface sediments, covered by transgressive shelf facies.

goniatites; corals, the most abundant of which are *Lophophyllidium profundum* and species of *Caninia*; conularids; bryozoans of both encrusting and fenestrate forms; and small phosphatic (spiral) coprolites.

Distribution of the Perrin Delta System

The Perrin delta system was a persistent feature during most of Missourian time, as shown by thick terrigenous clastic facies in three consecutive Canyon stratigraphic intervals.

Interval 1: Wolf Mountain/Winchell Formations.--During Canyon deposition, the Perrin delta system prograded west to northwest through Jack and Wise counties (Fig. 5), as evidenced by the orientation of thick deltaic facies in outcrop (Plates I and II). Thick carbonate bank limestone facies of the Winchell Formation, which crop out in the Lake Possum Kingdom area of northwestern Palo Pinto County interfinger to the north with fossiliferous, delta-flank mudstone and strike-fed sandstone units (Fig. 5). From immediately southwest of Perrin in southern Jack County, northeastward to the vicinity of Bridgeport in western Wise County, thick deltaic sandstone and mudstone facies crop out along a northeast-southwest belt (Plate I). The Chico Ridge Limestone, a thick carbonate bank sequence, which flanks the Perrin delta system on the northeast, crops out in the Lake Bridgeport area (Plate I and Fig. 5).

A net sandstone thickness map (Plate IV) of the Wolf Mountain Formation displays dip-oriented, linear and bifurcating sandstone trends interpreted to be framework sandstone facies of the

Perrin delta system. Delta lobes extend for as much as 80 miles west and northwest into the subsurface from outcrops in Jack and Wise counties. Maximum thickness of sandstone in the Perrin delta system occurs only 5 to 10 miles down-dip from outcrop near Jacksboro in south-central Jack County. A series of Perrin lobes merged with Henrietta fan delta lobes in southern Clay County. In western Jack County, Perrin delta lobes shifted to a westward orientation and prograded across Young and southern Archer counties into Throckmorton and Baylor counties. This shift in trend may have resulted from the influence of the contemporaneous Winchell carbonate bank, which exhibited slight depositional relief southwest of the Perrin delta system (Plate V). Areas containing only minor net sandstone values probably represent interdistributary and interdeltaic embayments.

Thick accumulation of sandstone facies in northern Throckmorton County may have resulted from the influence of the Bend Arch, which trends generally north-south through western Young County (Fig. 3). During deposition of the Wolf Mountain Formation, the arch possibly marked a break in slope, beyond which water depth increased significantly. When prograding lobes of the Perrin delta system reached this break, the rate of progradation diminished, and thicker deltaic sands were deposited in the deeper water. This process is analogous to what is now occurring with the birdsfoot lobe of the modern Mississippi delta, where distributaries have prograded into relatively deep water. In order for the Mississippi system to prograde basinward, thick sequences of deltaic sediments must accumulate.

Minor delta lobes prograded northwestward through Palo Pinto, Stephens and Shackelford counties (Plate IV). Progradation of these minor lobes was not contemporaneous with deposition of the northern part of the Perrin delta system, but rather preceded the major delta-building event. Sandstone units of one of these minor deltaic lobes crop out northwest of Strawn, Texas (Fig. 11).

Progradation of the Perrin delta system during deposition of the Wolf Mountain Formation (Fig. 17) was, in part, contemporaneous with deposition of the Chico Ridge carbonate bank system to the northeast and the Winchell carbonate bank system to the southwest. Bank deposition began as algal-crinoid mounds growing on abandoned deltaic and interdeltaic sediments in the lower part of the Wolf Mountain Formation. Lobes of the Perrin system prograded westward across the Eastern Shelf between these shoal-water carbonate banks. Electric logs clearly distinguish between the carbonate bank and deltaic facies (Fig. 18). In outcrop, carbonate bank facies exhibit intercalated beds of terrigenous silty and sandy clay up to 3 feet thick. These terrigenous clastic units record periods of local influx from nearby deltaic lobes of the Perrin system. Shifting delta lobes introduced fine terrigenous clastics, which temporarily eliminated the carbonate-producing and trapping organisms, restricting carbonate deposition to less turbid sites.

Winchell and Chico Ridge carbonate banks probably influenced the route of prograding Perrin delta lobes; deltaic lobes appear to have deflected around the banks (Fig. 17). Near the end of Wolf Mountain deposition, the carbonate banks probably had little, if any, depositional relief. The banks, which likely originated with depositional relief, ended up as carbonate lagoons partially surrounded by deltaic lobes. Pollard (1970) believed that the Winchell Limestone near Lake Possum

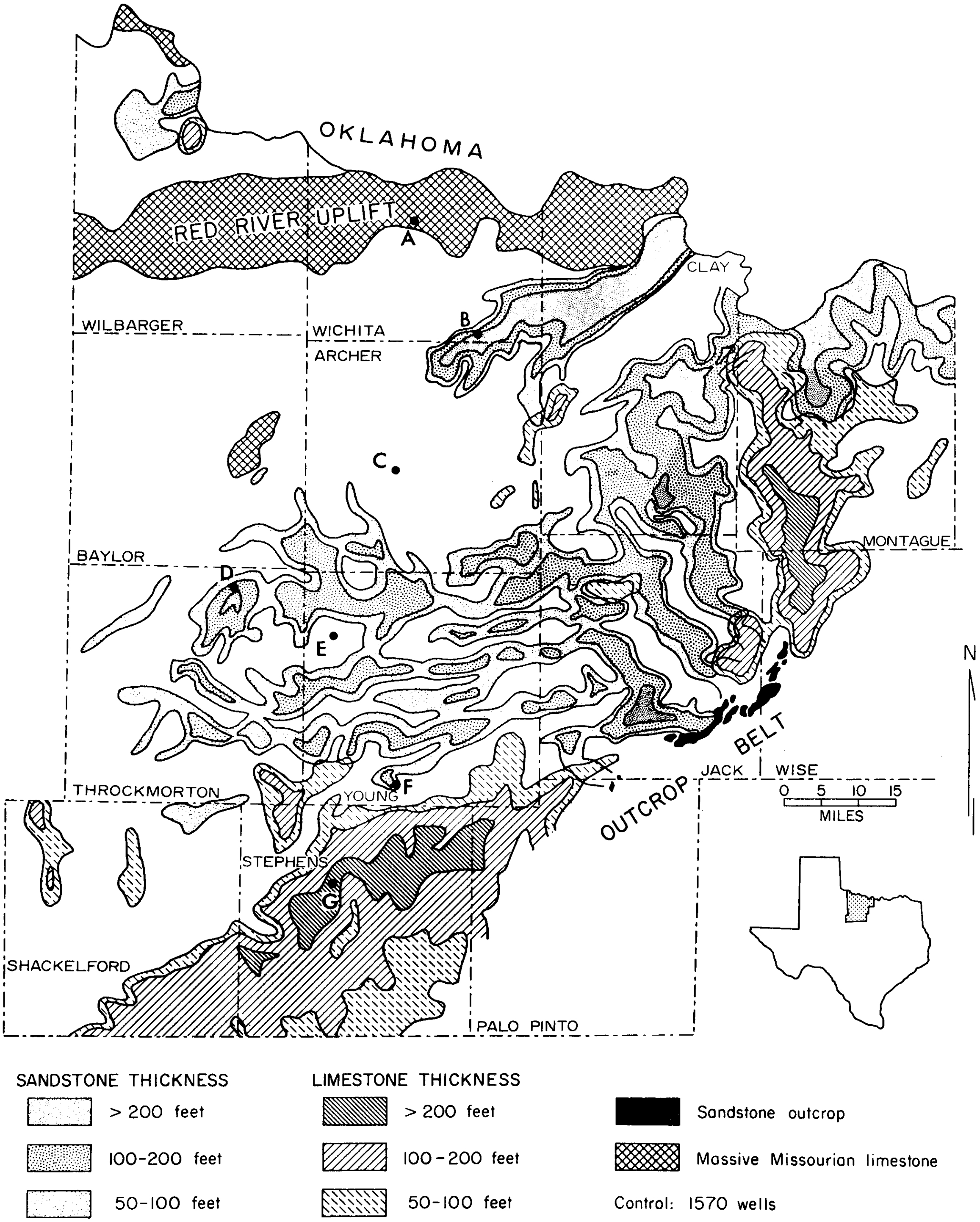


Figure 17. Net limestone thickness map for the Winchell Limestone superimposed upon net sandstone thickness map for the Wolf Mountain Formation. Deltaic lobes of the Perrin delta and Henrietta fan delta systems prograded basinward contemporaneous with carbonate bank accumulation; as the Perrin delta was abandoned, algal carbonates spread out from the bank areas. Letters (A-G) refer to typical E-log patterns illustrated in Figure 18.

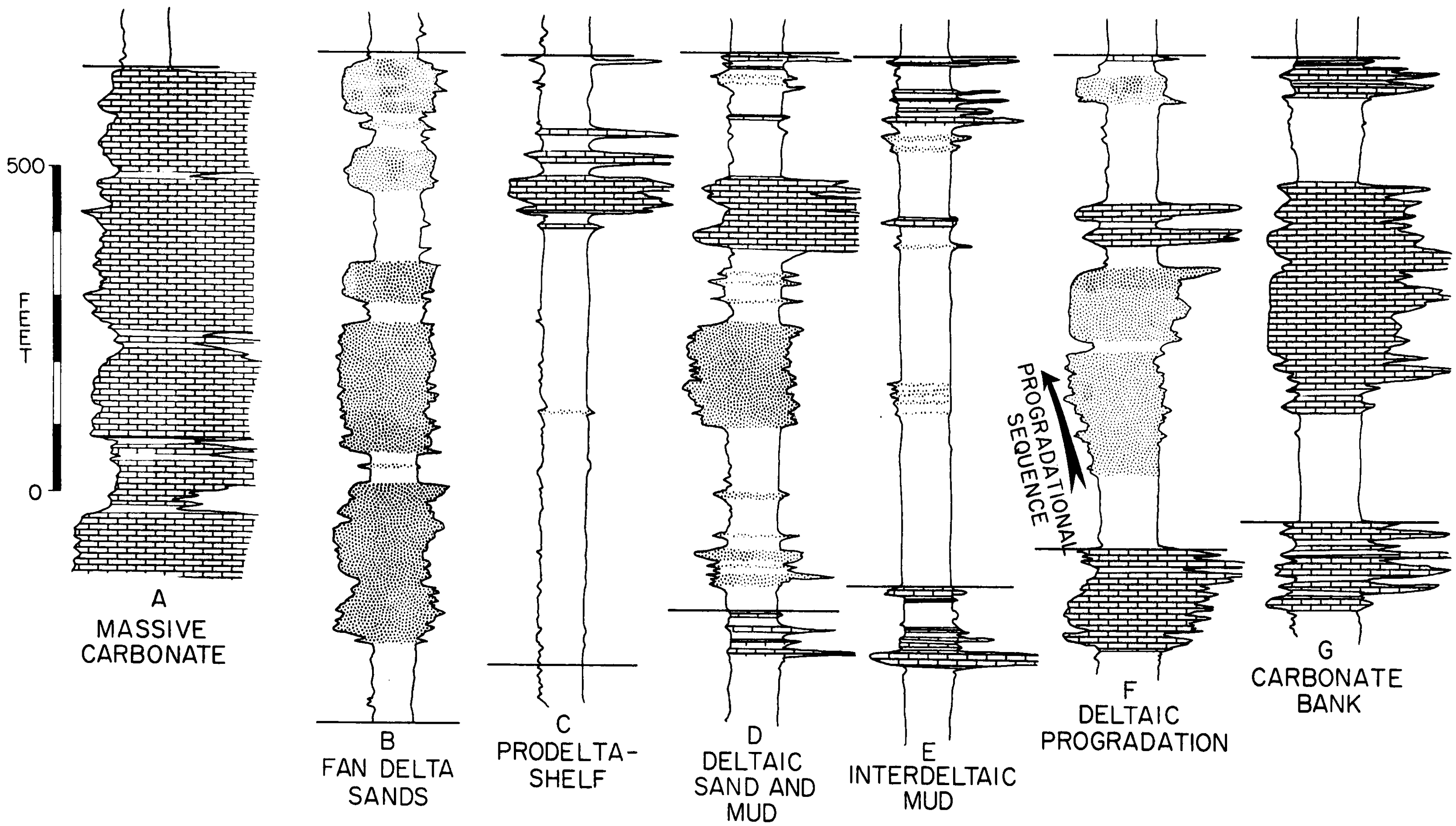


Figure 18. Typical E-log patterns of facies within Canyon depositional systems, North-Central Texas; see Figure 17 for locations of E-logs.

Kingdom exhibited only local depositional relief and was, for the most part, a flat carbonate biostrome. Raish (1964), on the other hand, recognized peripheral sloping wedges of oolitic and bioclastic calcarenite, which he inferred were shed from the depositionally high Chico Ridge algal bank.

The Rock Hill Limestone (Fig. 5; Plate I), a thin (less than 3 feet) intramicrudite and/or carbonate breccia deposit, was shed from the Chico Ridge bank early in its development. Angular limestone clasts up to 2 inches in diameter, molluskan debris, crinoid columnals, and corals are mixed within a fine calcarenite and micrite matrix. The Rock Hill Limestone thins and pinches out away from the Chico Ridge carbonate bank over a distance of about 7 miles (Plate I). Angular clasts of micrite, containing local crinoidal and algal debris, must have been partially to completely lithified before they were swept from the bank and redeposited. It is evident, therefore, that the Chico Ridge carbonate bank must have undergone local periods of subaerial exposure required for the lithification of lime mud. More about the carbonate banks follows in a later section.

With abandonment and subsidence of the Perrin delta, algal carbonate facies spread from adjacent carbonate banks and onlapped the edges of the foundering delta lobes, giving rise to the transgressive, sheet-like Winchell Limestone tongue of southern Jack County and the equivalent Devil's Den Limestone tongue of eastern Jack and western Wise counties (Fig. 5). Continued progradation of minor distributaries, as well as marine reworking of foundering Perrin delta lobes in southeastern Jack County, prevented complete overlap by Winchell - Devil's Den carbonate facies. In this region, therefore, deltaic clastics

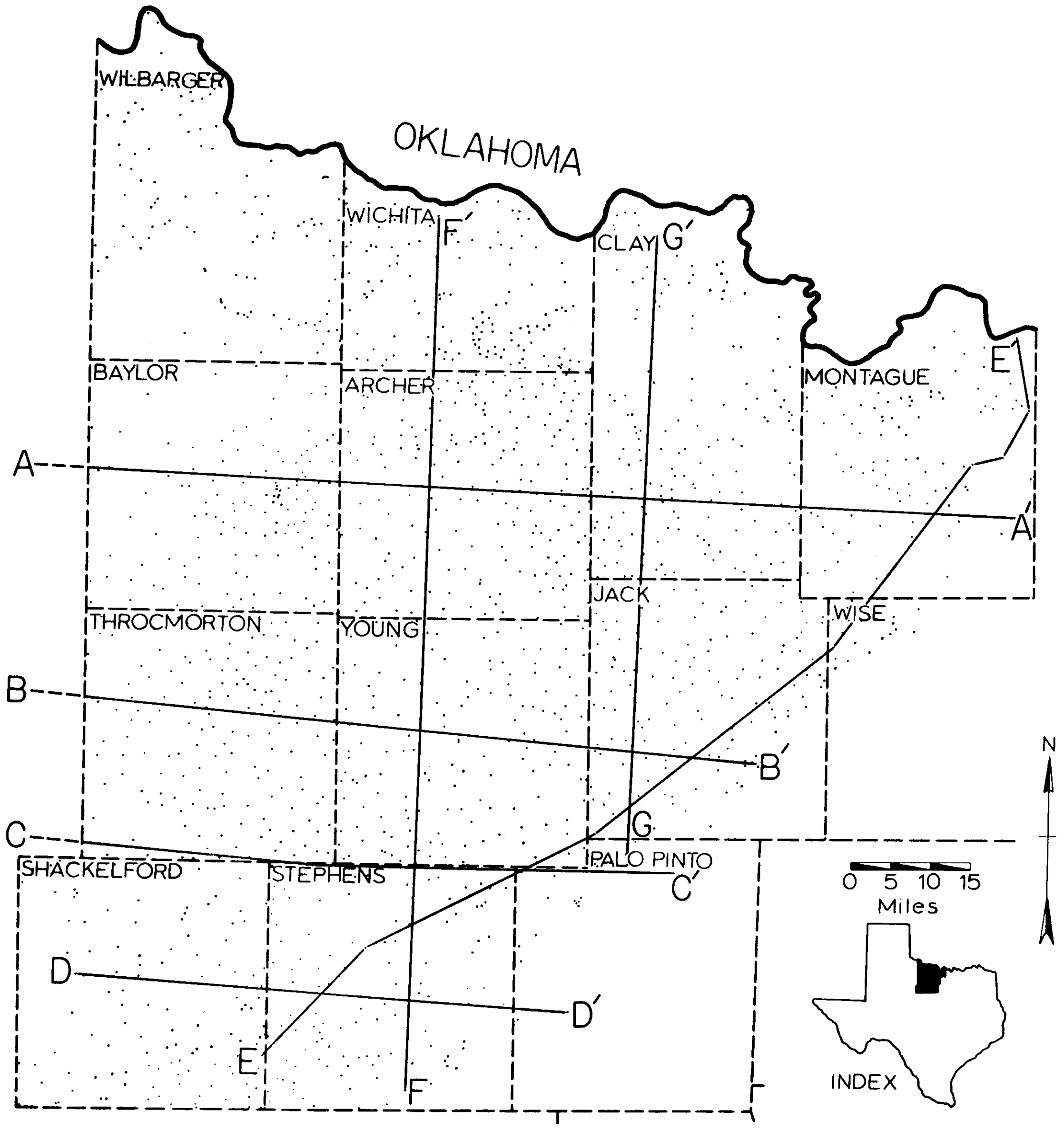


Figure 19. Index map showing positions of Canyon Group cross sections in North-Central Texas; all cross sections employ the top of the Home Creek Formation as the stratigraphic datum (well names and locations on open file, Bureau of Economic Geology, The University of Texas at Austin).

of the Placid Formation rest directly upon similar facies of the underlying Wolf Mountain Formation (Fig. 5, Plate II).

The lateral and vertical relationships between terrigenous clastic and carbonate facies is shown by regional cross sections (Figs. 20, 21 and 22). The predominance of carbonate and shelf mudstone facies in Palo Pinto and Stephens counties contrasts sharply with the thick deltaic, terrigenous clastic facies in Jack, Wise and Montague counties (Section E-E', Fig. 21).

Interval 2: Placid Formation.--From the Sparks Springs area of southern Jack County (Plate I) northeastward to the Cretaceous overlap, the outcropping Placid Formation is a complex facies association composed of laminated prodelta mudstone, delta-front and distributary channel-fill sandstone, reworked sandstone and siltstone, fossiliferous interdistributary mudstone, local contorted bar-finger sandstone and local coarse-grained fluvial sandstone and conglomerate. From the vicinity of Sparks Springs Church (Plate I), outcropping delta facies thin and interfinger southwestward with interdeltaic embayment mudstone. Abandoned deltaic environments were ultimately overlapped by highly fossiliferous shelf mudstone and algal carbonate of the Ranger Limestone during transgression (Plates III and VII).

A net sandstone map of the Placid Formation (Plate VI) shows that Perrin delta lobes in outcrop are part of a system, which prograded to the northwest and west across northern Jack, northwestern Wise and southern Clay and Montague counties. Axes of thick sandstone facies in the subsurface north of Wizard Wells tie with outcropping Perrin deltaic sandstone units, principally massive, contorted barfinger sandstone

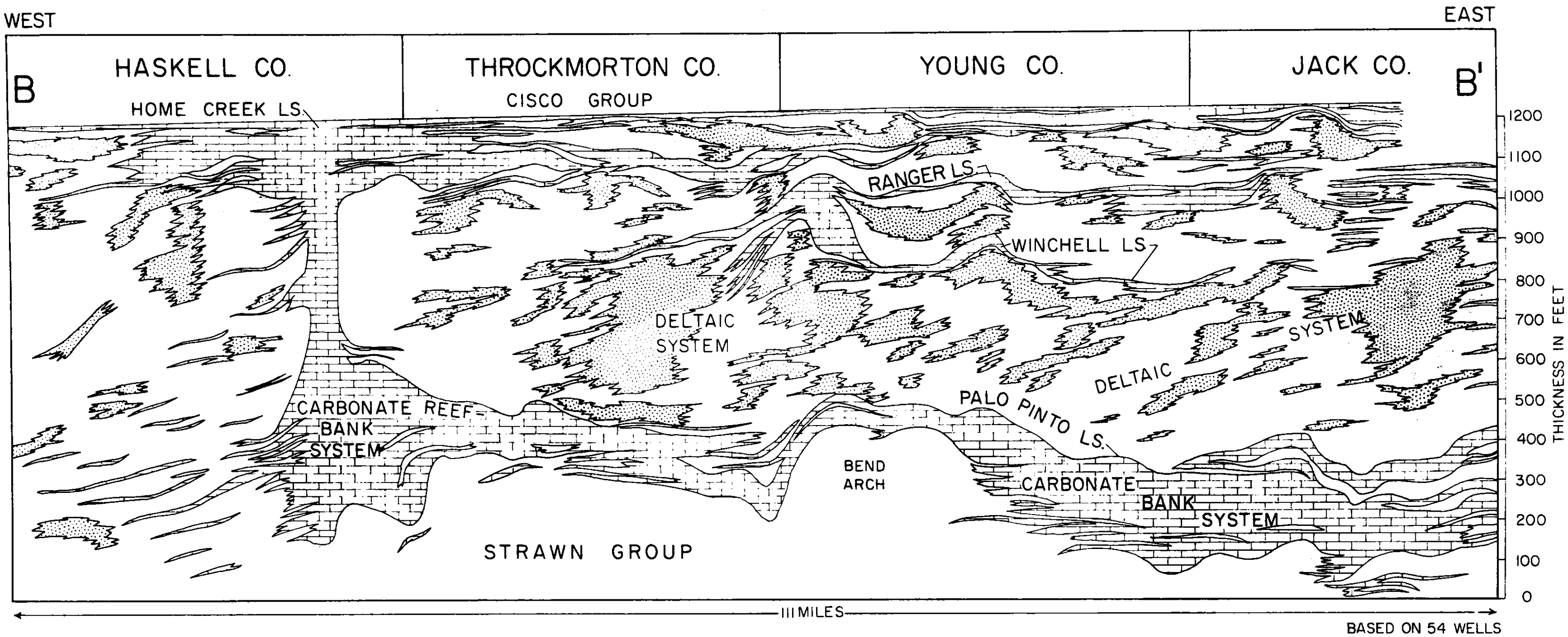


Figure 20. Subsurface cross section B-B′ (dip) from Jack County on the east to western Haskel County, Texas, on the west, showing deltaic and carbonate facies of the Canyon Group; based on 54 electric and sample logs; see Figure 19 for line of section.

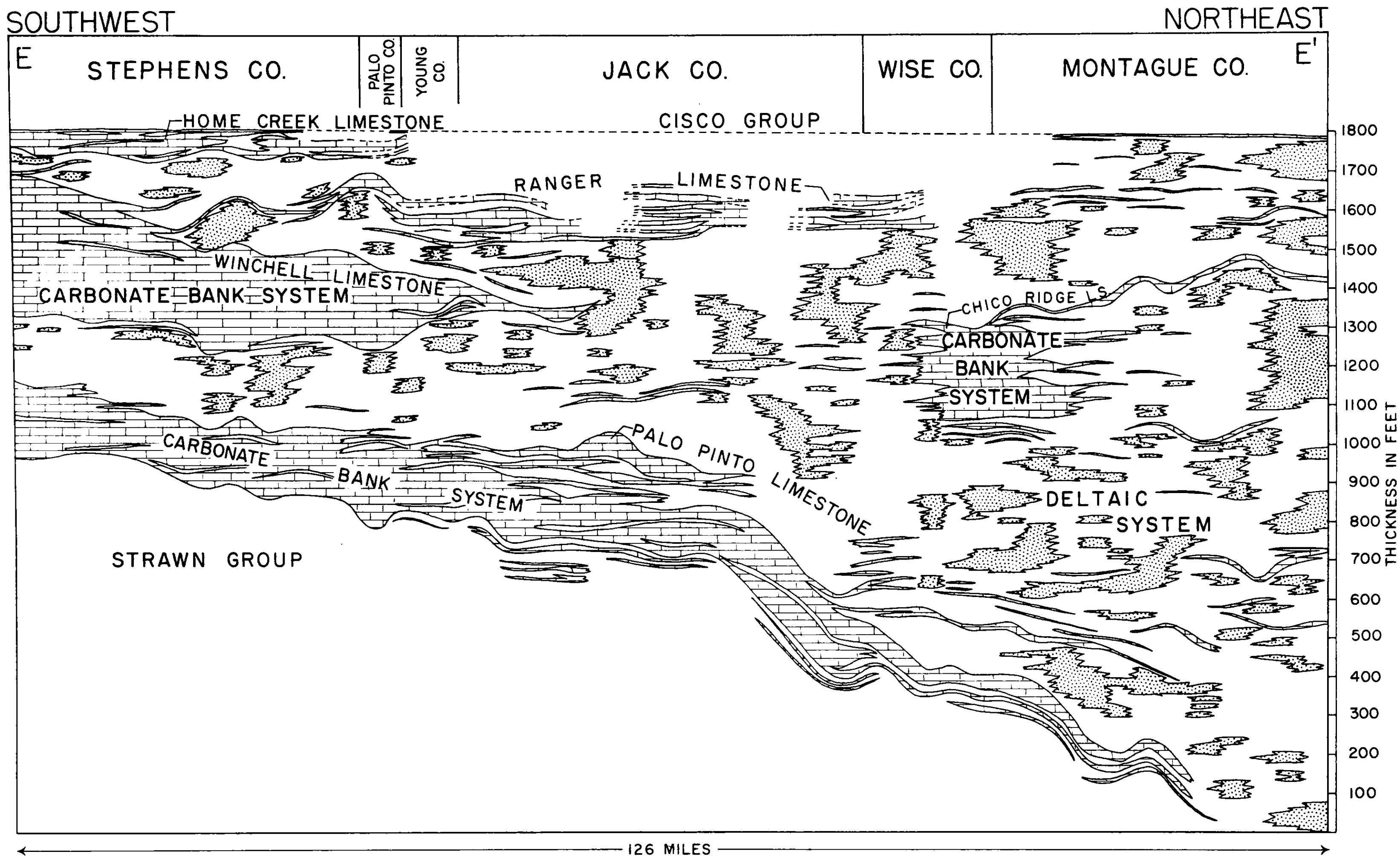


Figure 21. Shallow subsurface cross section E-E′ (strike) from Stephens to northern Montague Counties, Texas, showing facies of the Canyon Group; based on 48 electric and sample logs; see Figure 19 for line of section.

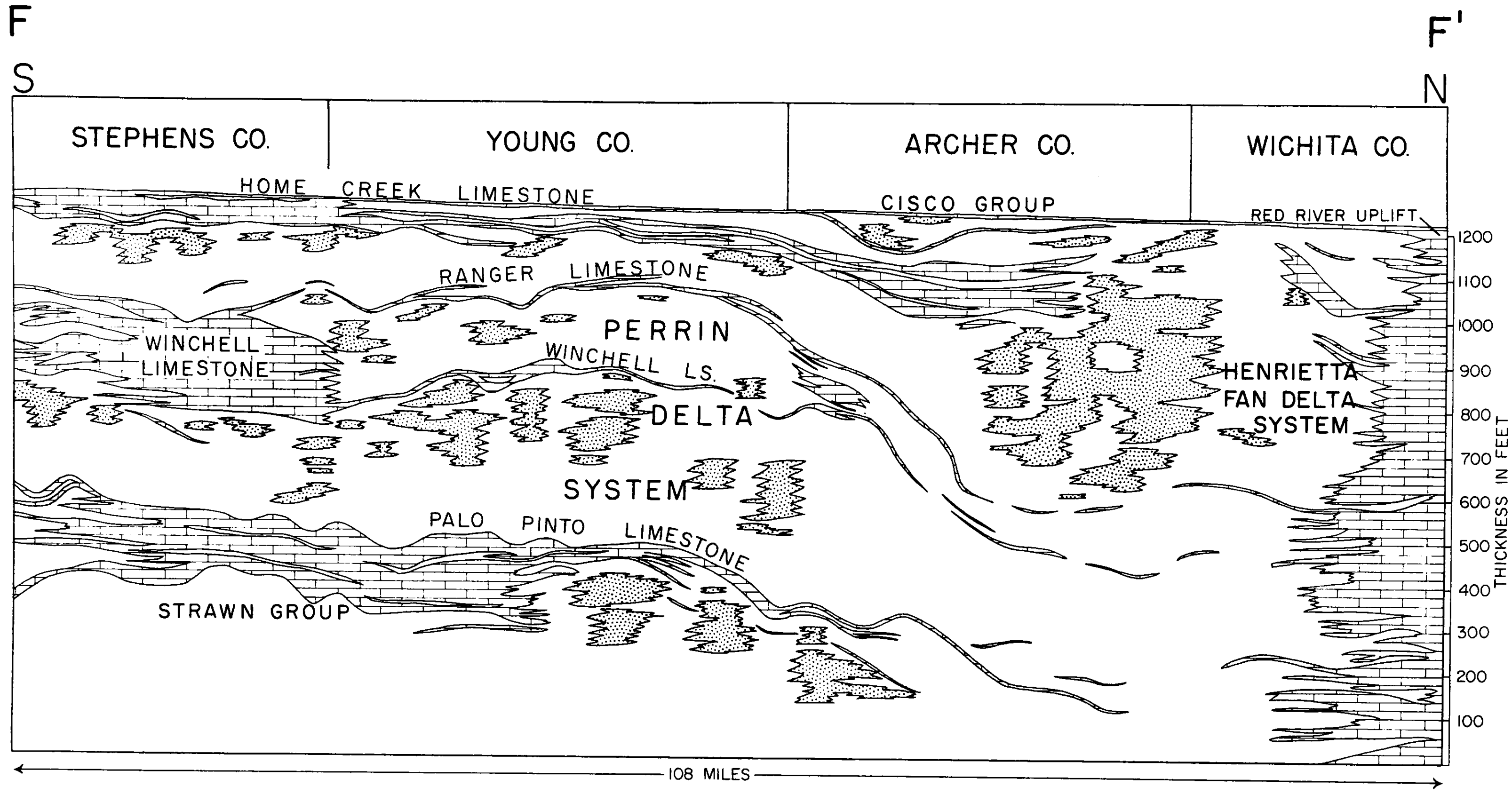


Figure 22. Subsurface cross section F-F′, from Stephens Country northward to northern Wichita County, Texas, showing deltaic and carbonate facies of the Canyon Group, based on 45 electric and sample logs; see Figure 19 for line of section.

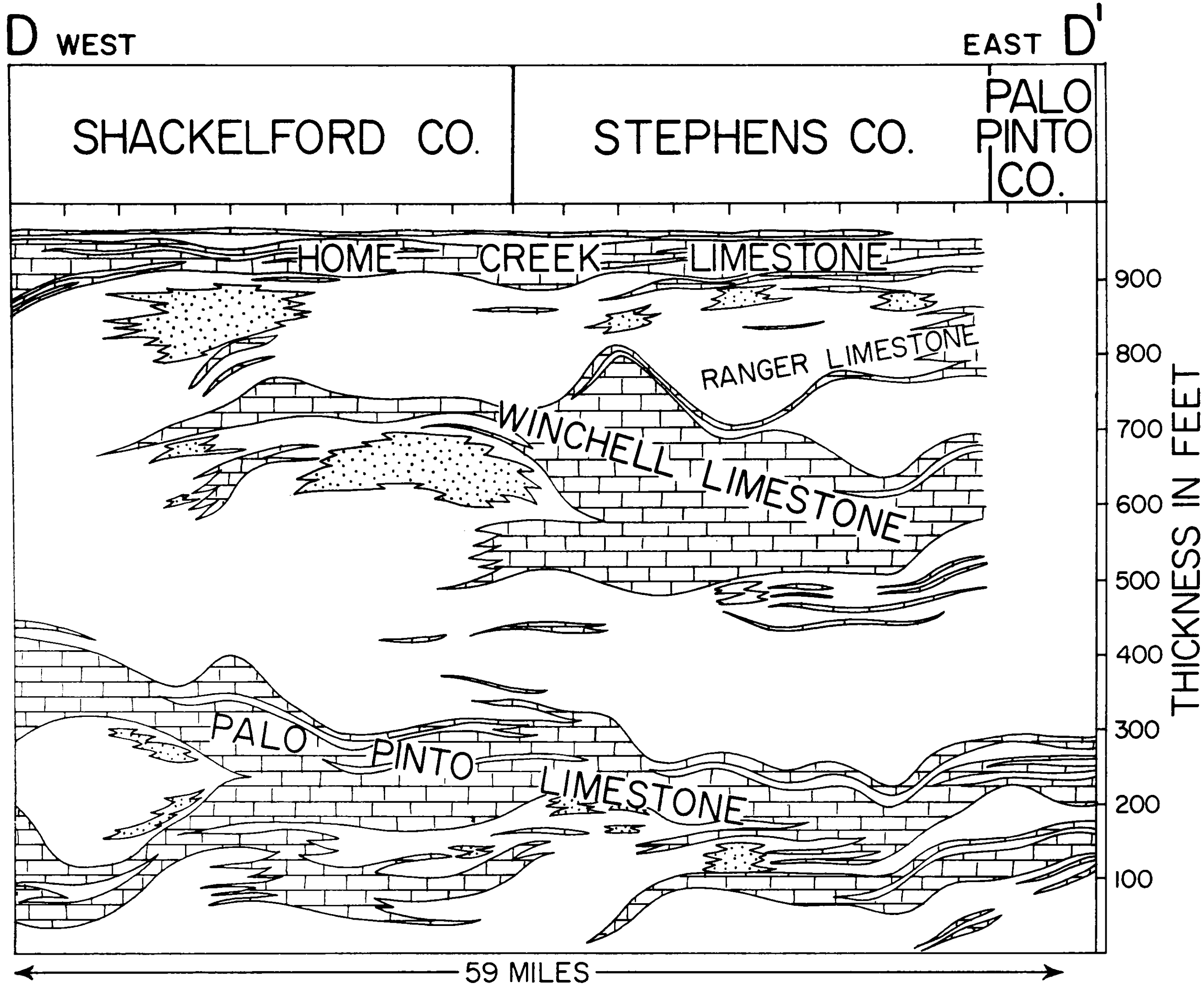


Figure 23. Subsurface cross D-D′ from near outcrop in Palo Pinto County westward to western Shackelford County, Texas, showing carbonate and shelf mudstone units and local deltaic sands of the Canyon Group; based on 20 electric and sample logs; see Figure 19 for line of section.

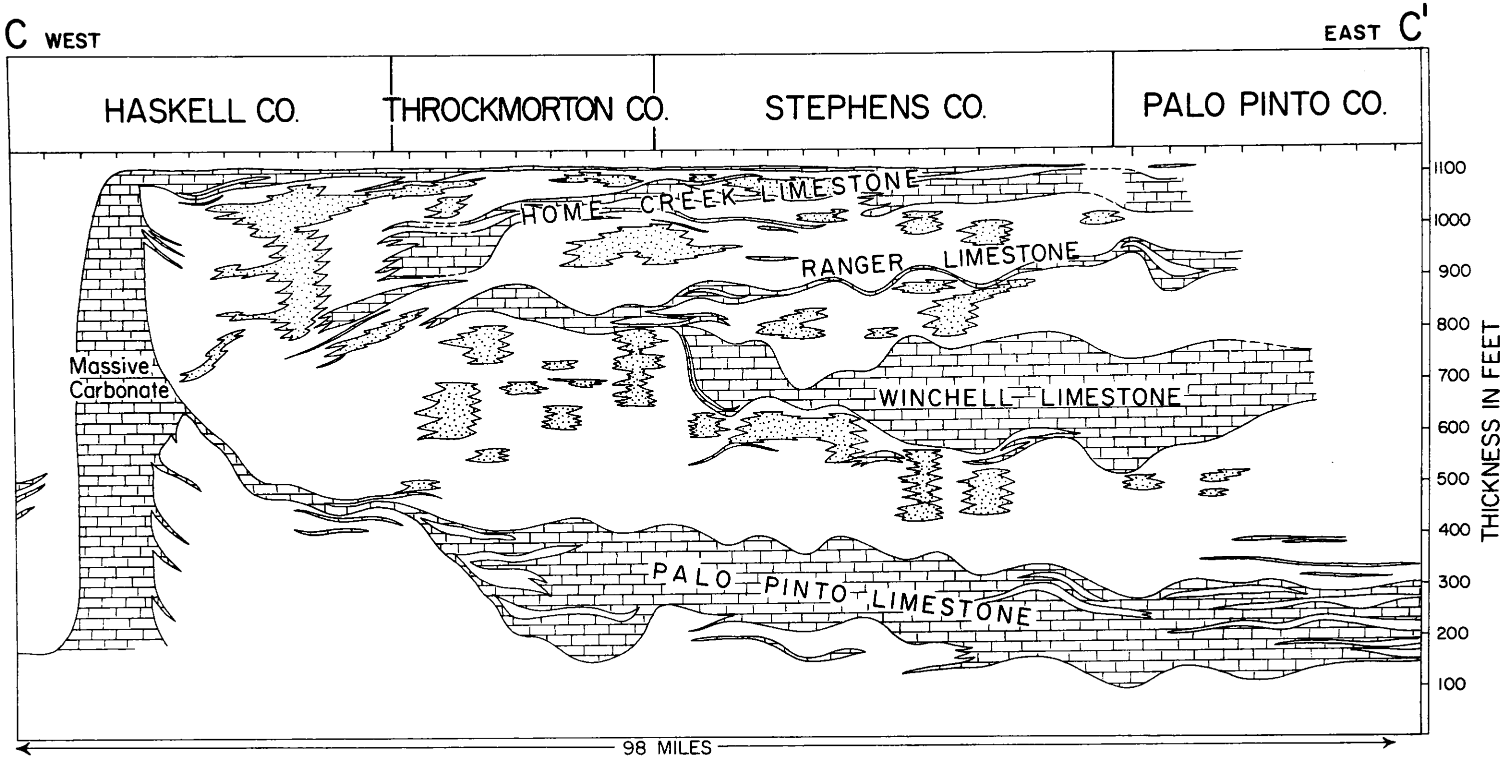


Figure 24. Subsurface cross section C-C', from near outcrop in Palo Pinto County westward to western Haskell County, Texas, showing Canyon Group deltaic sandstone and mudstone units separated by shelf carbonates with a massive reef-bank carbonate buildup near the Missourian shelf edge; based on 39 electric and sample logs; see Figure 19 for line of section.

units (Plate III). South of Wizard Wells, two thin delta lobes prograded westward; a small system, which prograded a short distance across southern Jack and northern Palo Pinto counties, crops out in the Halsell Ranch area (Plate I; Measured Section 31). A large, bifurcating lobe prograded basinward across northern Stephens and southern Young counties. Delta lobes located in the subsurface of southern and eastern Montague County lie beneath a thin cover of Cretaceous sediments.

In western Stephens and southeastern Shackelford counties, mudstone and sandstone facies of the Placid Formation grade laterally into massive carbonate of the combined Winchell and Ranger Limestones (Figs. 21, 22, 23 and 24). Deltaic deposits in the Placid Formation in Jack, Wise and northern Palo Pinto counties are inferred to have been time-equivalent with carbonate bank deposits in Stephens and Shackelford counties.

In the subsurface of western and central Baylor County, extensive, thick sandstone facies apparently prograded from the northwest (cross section A-A', Fig. 25). Wermund and Jenkins (1970) show second-derivative trend surface maps that outline a large, inferred delta lobe, which extended southward across the Northern Shelf through Foard, Knox and into western Baylor County during Middle and Late Missourian time.

In the vicinity of Highway 380 and Farm to Market Road 1156, west of Wizard Wells (Fig. 5; Plate III), thin, ripple cross-stratified, laterally reworked quartz sandstone beds lie between two principal limestone members of the Ranger Formation. Algal-crinoid carbonate

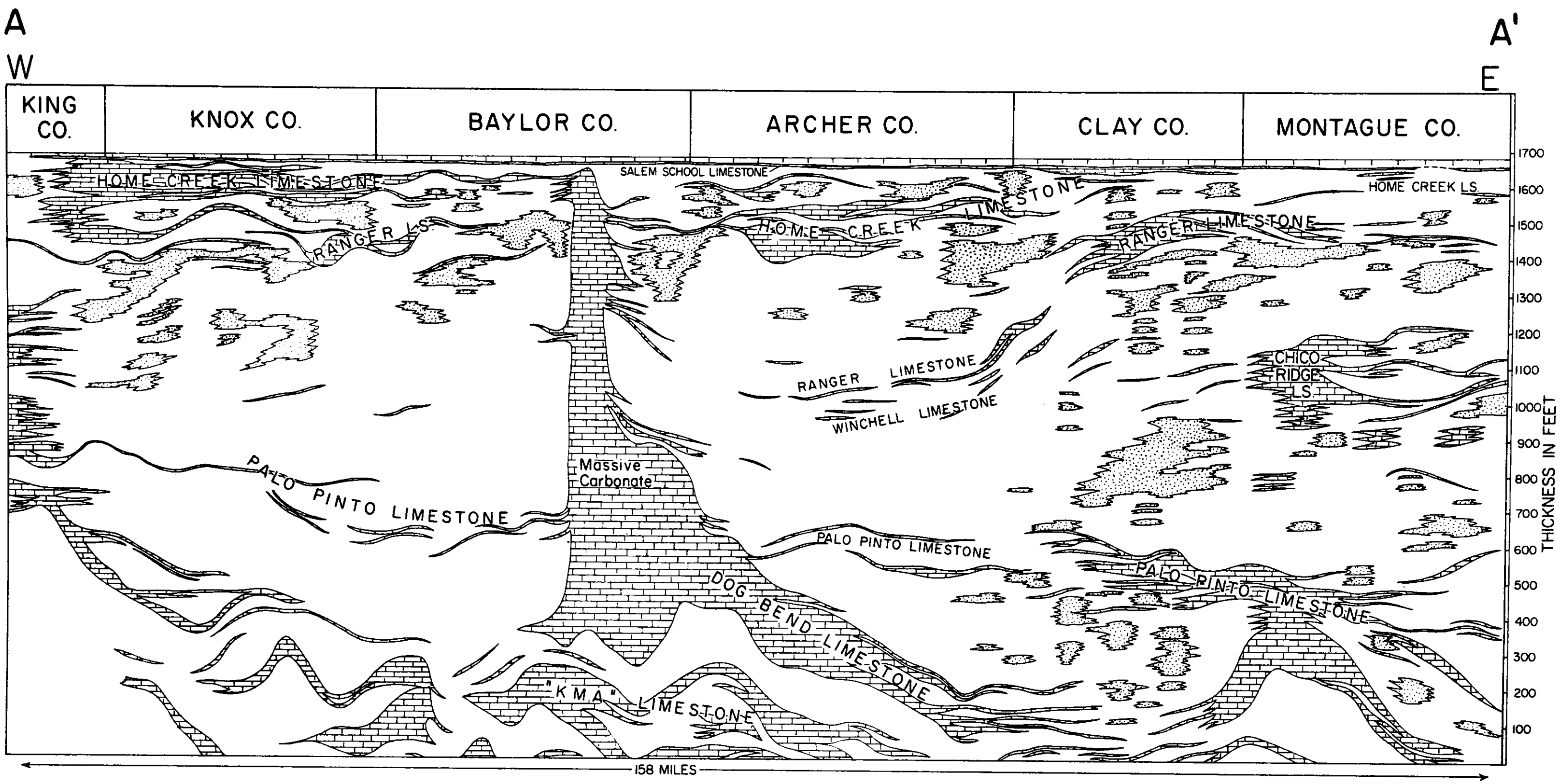


Figure 25. Subsurface cross section A-A' (dip) from the shallow subsurface of eastern Montague County westward to eastern King County, Texas, showing deltaic and carbonate facies of the Canyon and Upper Strawn Groups with a massive reef-bank carbonate buildup in eastern Baylor County; based on 59 electric and sample logs; see Figure 19 for line of section.

in the lower Ranger limestone member was deposited contemporaneous with deltaic sediments a few miles to the southwest in the State Highway 199 - Beans Creek area (Plate I). As the delta lobes were gradually abandoned, marine processes reworked delta-front and distributary channel facies and spread the clastic sediments along strike, eventually overlapping the lower limestone member of the Formation. Eventually, the upper member of the Ranger Limestone transgressed the entire Placid clastic sequence (Fig. 5).

Interval 3: Colony Creek Formation.--With initiation of Colony Creek deposition, delta lobes prograded over updip Ranger shelf carbonate facies. Elimination of Ranger limestone deposition occurred at different times on various parts of the Eastern Shelf; for example, Ranger Limestone deposits in Stephens and Shackelford counties may be time-equivalent with Perrin deltaic facies to the northeast within the Colony Creek Formation. The distribution of lithofacies (Plate I, Fig. 5) demonstrates that deltaic lobes prograded basinward through central Jack and Wise counties during deposition of the Colony Creek interval. Composition, sedimentary structures and stratigraphic relationships of Perrin sandstone and mudstone facies within the Colony Creek Formation resemble those in the underlying Wolf Mountain and Placid Formations. Plant-rich, fine-grained deltaic sandstone units overlie and flank sandy prodelta mudstone facies. Within the Colony Creek Formation, fluvial channels filled with coarse-grained sandstone and conglomerate cut finer subjacent deltaic sandstone and mudstone units; these channel-fill deposits crop out east and northeast of Jacksboro. The Cundiff Limestone, which occurs within the Colony Creek

Formation south of the community of Cundiff in eastern Jack County (Plate I), is a thin, algal and crinoid-rich facies that was probably deposited within a local bay-lagoon environment that formed following abandonment of an early Colony Creek deltaic lobe.

Lobes of the Perrin delta system extended downdip for 45 miles beyond outcrops in Jack and Wise counties (Plate VIII). Principal Perrin fluvial-deltaic facies within the Colony Creek Formation (Plate VIII) extend basinward across western Jack, northeastern Young, southeastern Archer and southwestern Clay counties from outcrops north and west of Barton's Chapel (Plate I). At outcrop, these facies include thick, fluvial conglomerate units, which overlie and locally eroded finer, subjacent deltaic facies. Two linear trends composed of 100 to 150 feet of net sandstone extend northwestward downdip from outcrop; thick narrow belts on the net sandstone map may reflect the downdip limits of the coarse-grained fluvial facies.

Relatively thin, minor Perrin delta lobes, which trend westward across southeastern Young and central Stephens counties, may be observed at the outcrop in southern Jack, northwestern Palo Pinto and eastern Stephens counties. Thin, ripple cross-stratified, fine- to very fine-grained marine sandstone units of strike-fed delta destructional origin are common in the Colony Creek interval south of Lake Possum Kingdom (western Palo Pinto and eastern Stephens counties). In northwestern Stephens, southwestern Young, southeastern Throckmorton and northern Shackelford counties, narrow, high net sandstone values (Plate VIII) define northeast-southwest trends, which may represent strike-fed barrier islands or strand-plain sequences composed of sand derived from Perrin delta lobes to the northeast and Henrietta fan delta lobes to the north.

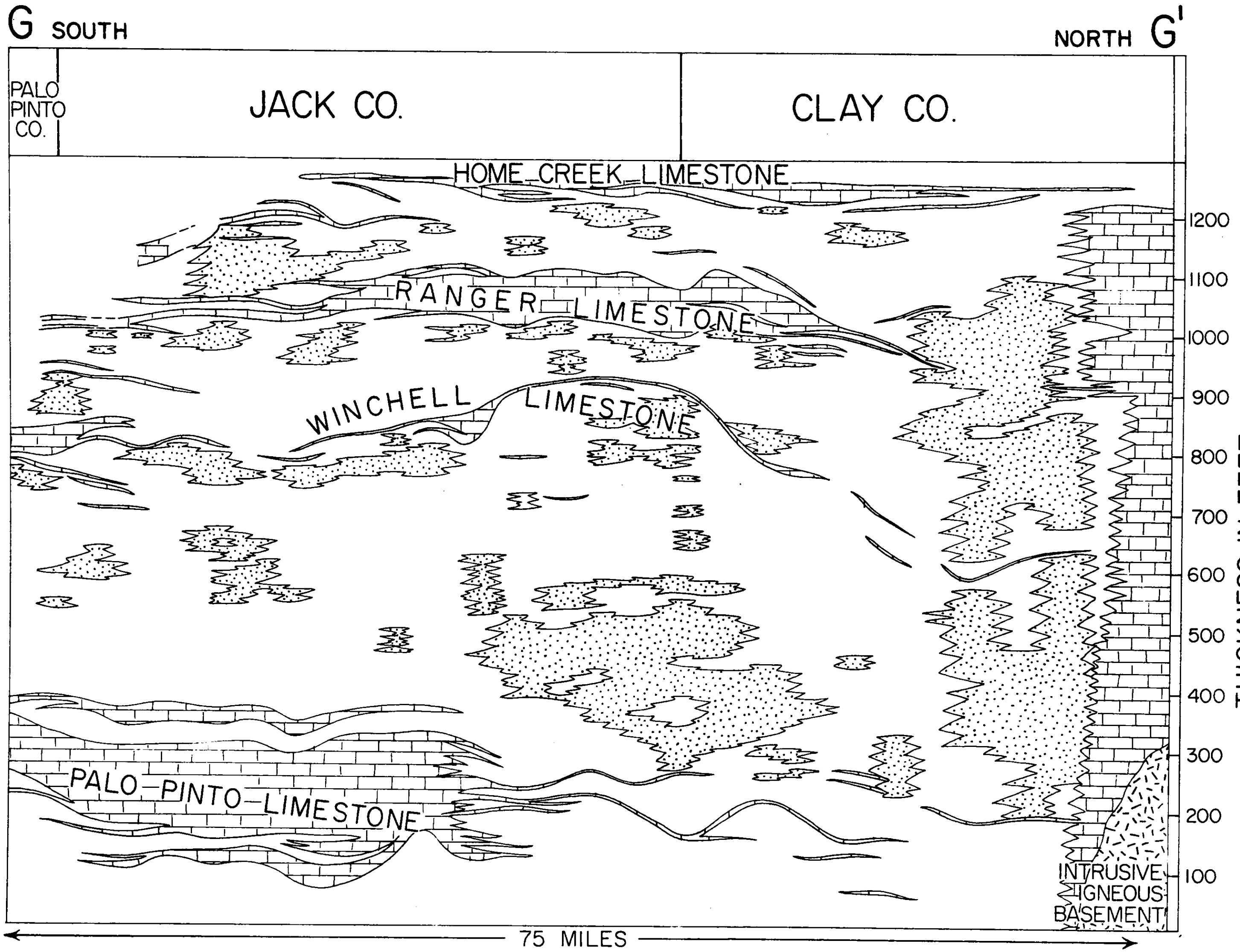


Figure 26. Subsurface cross section G-G' (strike) from the shallow subsurface of Palo Pinto County northward to northern Clay County, Texas, showing deltaic and carbonate facies of the Canyon Group. Massive carbonate platform facies cap intrusive igneous rocks of the Red River Uplift in northern Clay County; based on 28 electric and sample logs; see Figure 19 for line of section.

These strike-oriented linear sandstone trends appear to be isolated from principal dip-oriented net sandstone trends of either the Perrin system or the Henrietta system. Individual strike-oriented sandstone units are 10 to 60 feet thick; electric log patterns in these sandstone units exhibit blocky spontaneous potential and resistivity profiles, with relatively sharp tops and bases. Well developed, coarsening-upward sequences, common in deltaic facies, were not recognized on electric logs through these strike-oriented units.

Locally, in south-central Shackelford County, the entire Colony Creek Formation is replaced by massive carbonate with thin, intercalated shaly beds (Plate VIII); the carbonate sequence terminates upward at the top of the Home Creek Limestone. Absence of terrigenous clastic facies in this area permitted carbonate deposition to continue throughout most of Missourian time. Periodic influx of terrigenous sediment from prograding deltas to the north and east locally and temporarily eliminated carbonate deposition. Nevertheless, algal-crinoid bank shoals and sheet-like biostromal deposits persisted in the south-west contemporaneous with deposition of deltaic lobes to the northeast (Plate VIII).

Depositional History of the Perrin Delta System

The high-constructive Perrin delta was a persistent system of west- and northwest-trending lobes that prograded across the Eastern Shelf throughout most of Missourian time (Fig. 27). Early delta development began during deposition of the lower part of the Wolf Mountain Formation of Wise, Montague, Palo Pinto and Stephens counties, when relatively

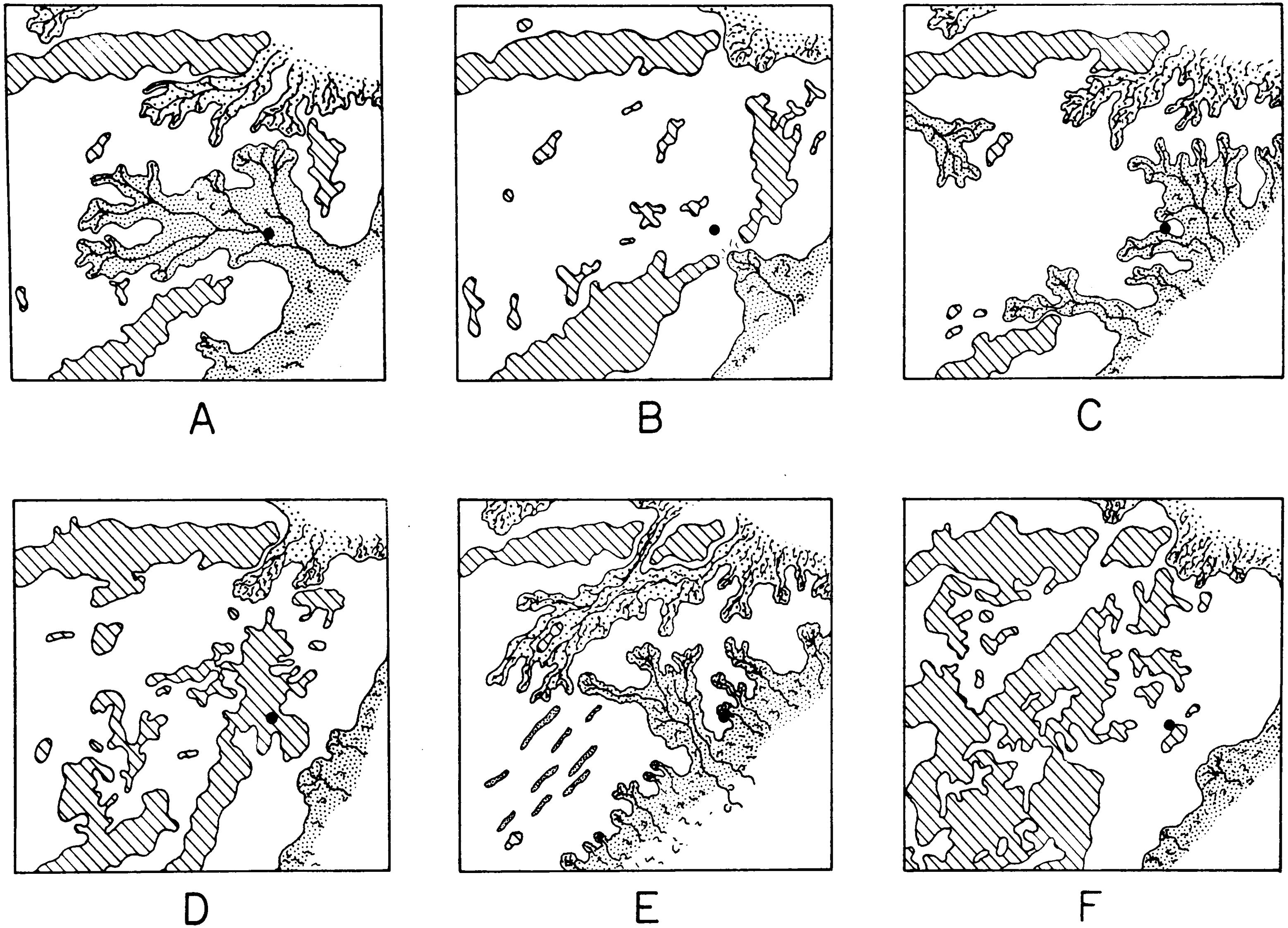


Figure 27. Evolution of paleogeography, Canyon depositional systems, North-Central Texas; fine stipple indicates high constructive elongate and lobate delta system, coarse stipple indicates fan delta system, parallel lines indicate carbonate systems, black dot marks position of Jacksboro, Texas: A. Wolf Mountain time B. Winchell time C. Placid time D. Ranger time E. Colony Creek time F. Home Creek time.

minor delta lobes prograded west and northwest supplied by sources in the Ouachita Fold Belt. As these minor lobes were abandoned and began to subside, shoal-water, algal-crinoid banks became established on the foundering deltaic platforms. These banks, the Winchell carbonate bank and the Chico Ridge carbonate bank, remained depositionally high with respect to the surrounding sea floor (see evidence in a later section). Brecciated carbonate talus beds, such as the Rock Hill Limestone of western Wise County, were periodically shed from the elevated carbonate environments.

Following the establishment of the Winchell and Chico Ridge banks during middle Wolf Mountain deposition, major high-constructive Perrin deltas prograded westward across Jack County. The path of the prograding system may have been, in part, controlled by the presence of the carbonate banks to the north and south.

Longshore currents and waves reworked abandoned deltaic facies and transported terrigenous sediment along strike. Thin blankets of terrigenous silt and clay, which were intermittently deposited over lime mud and phylloid algae on the carbonate banks, caused local termination of carbonate deposition, marked by thin terrigenous clastic beds within the carbonate sequences. In this manner, strike-fed sand and mud from the Perrin delta system of Jack County interfingered to the southwest and northeast with carbonate bank facies in the Lake Possum Kingdom and Lake Bridgeport areas, respectively.

During deposition of the Wolf Mountain Formation, and the lower and middle parts of the Winchell and Chico Ridge Limestones, the Perrin delta system prograded across Jack, Young, southern Clay, southern

Archer, southeastern Baylor and eastern Throckmorton counties. Following abandonment and subsidence of the delta lobes, the Winchell Limestone of northern Palo Pinto and southern Jack counties and the Devil's Den Limestone of Jack and Wise counties spread laterally from the carbonate banks and onlapped the Perrin delta system. Continued, but local, progradation of minor deltaic lobes, as well as marine reworking of deltaic sand, prevented transgressive Winchell carbonates from completely overlapping the deltain southeastern Jack County.

Renewed deltaic progradation, which marked the beginning of Placid deposition, overwhelmed transgressive carbonate environments in Jack, Wise, Montague, Clay, Palo Pinto and northern Stephens counties, but an elevated carbonate bank system persisted in western Stephens and southeastern Shackelford counties. High-constructive deltaic lobes again built northwestward and westward, in part contemporaneous with lower Ranger carbonate deposition in the area east and southeast of Wizard Wells, in eastern Jack County. With gradual abandonment of this phase of Perrin delta progradation, carbonate facies of the Ranger Limestone shelf overlapped the subsiding delta.

For a third and final time, transgressive shelf carbonate environments (Ranger Limestone) were overridden by thick deltaic lobes and coarse-grained fluvial systems during Colony Creek deposition. Major Perrin delta lobes built northwestward across Jack, Wise, southwestern Montague, southern Clay, southeastern Archer and northern Young counties; whereas minor delta lobes built basinward across Stephens and southeastern Young counties. Linear, strike-oriented sandstones, which were deposited in southeastern Throckmorton, southwestern Young, northwestern Stephens and northeastern Shackelford counties, probably represent reworked, strike-fed barrier island and strand-plain facies that formed adjacent to the Perrin system. Upon final abandonment of the Perrin delta system, the transgressive Home Creek Limestone locally covered deltaic sandstone and mudstone facies of the Colony Creek Formation.

Deltaic and fluvial systems prograded across the Eastern Shelf many times from sources in the Ouachita Fold Belt. Brown (1969) stated that from 10 to 15 repetitive fluvial-deltaic sequences exist in the Cisco Group. Cisco deltas seem to have followed a paleosurface controlled by underlying Home Creek Limestone deposits.

Perrin Delta Model

A three-dimensional representation of a high-constructive Perrin delta lobe (Fig. 28) indicates that laminated, essentially unfossiliferous prodelta mud was deposited in front of advancing distributaries. Thinly bedded, commonly graded, distal delta-front fine sand and silty mud overrode the prodelta facies; thin organic-rich sandstone beds commonly slumped down the gently sloping face of the prodelta slope and became complexly contorted.

As delta distributaries prograded contemporaneously with nearby carbonate bank accumulation, proximal delta-front and distributary-mouth bar sand was deposited on thin-bedded distal sand and silt facies. Distributary channels scoured into underlying delta-front sand and interdistributary silt and mud. Locally, delta plain mud and silty mud with thin peat beds were deposited on and laterally adjacent to distributary channel-fill deposits. Generally, thin, delta plain deposits, which were reworked after delta abandonment, were not preserved. Thin,

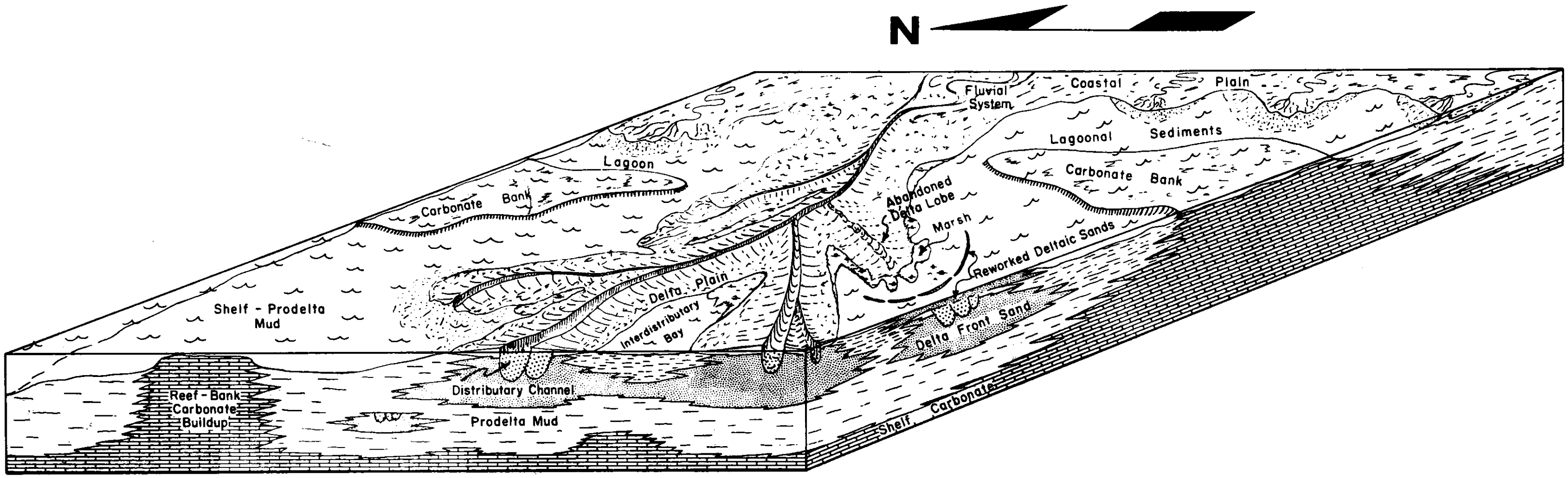


Figure 28. Block diagram model of a prograding high-constructive Perrin delta lobe showing gross facies framework and associated carbonate systems.

vuggy, bioturbated sandstone beds containing Myalina were commonly deposited on abandoned delta sequences. Following total delta abandonment and marine transgression, highly fossiliferous shelf mud, followed by superposed open-shelf algal carbonate, was deposited over abandoned delta environments. Thick deltaic sequences were deposited rapidly compared with relatively thin, highly fossiliferous shelf mudstone and open-shelf transgressive carbonate units.

The Holocene Guadalupe Delta at the head of San Antonio Bay, Texas, (Donaldson et al., 1970) bears similarities to the Perrin delta system. Distributary channels of the Guadalupe Delta have eroded underlying prodelta and bay deposits, a relationship common in the Perrin delta system. The Guadalupe Delta progrades into shallow water, as did the Perrin delta. Donaldson et al. (1970) suggested that this may account for the slight overlap and stacking of Guadalupe sub-deltas and for the relatively thin prodelta sequences. Subsidence of the Guadalupe delta is relatively slow and generally results from slight compaction of thin prodelta and estuarine muds.

The Mississippi Delta platform, on the other hand, significantly subsides within thick prodelta and delta-front facies. In the Gulf Coast Basin, Tertiary and Quaternary delta facies are stacked vertically. Under relatively stable tectonic conditions, such as those afforded by the Pennsylvanian Eastern Shelf, however, deltaic lobes tend to prograde rapidly and spread extensively, with little vertical stacking of facies (Brown, 1969). Delta plain sediments deposited under these conditions are thin, and the slow subsidence rates allow ample time for marine destruction of thin delta plain peats and peaty muds.

Somewhat similar delta models for Paleozoic rocks have been proposed by Pepper *et al.* (1954), Moore (1959), Allen (1959), Friedman (1960), Pryor (1961), Potter (1963), Wanless *et al.* (1963), Beerbower (1964), Swann (1964), Williams *et al.* (1964), Donaldson (1966, 1969), Duff (1967), Wright (1967), Brown (1969), Wanless *et al.* (1970), Galloway and Brown (1972) and Brown *et al.* (1973).

Henrietta Fan Delta System

Fan Delta Processes and Facies

A fan delta is an alluvial fan that progrades into a body of water from an adjacent highland (McGowen, 1970). "Fan delta" was first used by Holmes (1965) in referring to a delta at Lynton and Lynmouth on the Bristol Channel, Devon, England. Friedman and Johnson (1966) proposed the term "tectonic delta" for a delta composed chiefly of orogenic sandstone and conglomerate, contiguous to an active mountain front. Little difference exists between Friedman and Johnson's "tectonic delta" and a fan delta, as defined by McGowen (1970). Although modern terrestrial alluvial fans have received much attention by workers such as Blissenback (1954), Beaty (1963), Bull (1963), Denny (1964), Hooke (1967) and others, fan deltas have received relatively little study. McGowen (1970) presented what was probably the first complete study of the processes and sedimentary products of a small, active fan delta. Kidson (1953) described a flood on the Lynmouth fan delta, which transported boulders up to 20 feet in diameter and deposited 50,000 cubic yards of sediment on the delta in 24 hours.

Fan deltas, like alluvial fans, have relatively small drainage areas and flashy run-off. McGowen (1970) stated that during high flood stage, a sheet wash of small braided streams covers the entire surface of the Gum Hollow fan delta in Nueces Bay, Texas. As flood waters subside, a braided central channel is scoured down the axis of the delta. Gum Hollow delta aggrades only during periods of high run-off, such as during hurricanes and tropical storms.

Sedimentation on fan deltas is accomplished by the activity of relatively high-gradient braided streams. In as much as gradient is high and run-off is flashy, the ratio of coarse-grained to fine-grained sediments is much higher in fan deltas than in high-constructive lobate and elongate deltas. The braided fluvial system of a fan delta extends essentially all the way out to the toe of the delta. Distributaries are generally short and are themselves braided. The system is choked with bed-load sediment, which is transported only during peak run-off periods.

Thick, coarse-grained fan delta wedges tend to stack in localized areas along actively rising mountain fronts. Stacked alluvial fan and fan delta sediments are commonly bounded by a normal fault along a mountain front, which moves contemporaneous with deposition of the coarse facies. Maximum thickness of fan deposits occurs next to the source, adjacent to the bounding fault. Fan deltas, like alluvial fans, may be composed of feldspathic sand and gravel containing materials such as chert, limestone pebbles and cobbles, and poorly resistant rock fragments of various kinds. Preservation of non-resistant rock materials is possible because of the short transport distances.

trend extended across Wichita County near Wichita Falls, to terminate in northern Archer County near the town of Holliday.

The thick Henrietta lobe in northern Clay County is contiguous with the eastern end of the Red River carbonate platform. In less than 2 miles, the Missourian section changes from massive, coarse clastic facies of the Henrietta system to massive platform carbonate facies. The thick fan delta lobe may rest in a canyon cut through the eastern end of the carbonate platform, or the clastic system may have simply built around the end of the platform, contemporaneous with carbonate growth. Little interfingering of the massive clastic and carbonate facies occurs below the Ranger Limestone of northern Clay County (Fig. 26, Section G-G'). The thick sandstone and conglomerate facies of the Henrietta system occupy virtually the entire Canyon (Missourian) interval.

The Henrietta lobe of eastern Clay County exhibits a well-defined, thick, narrow trend, which extends southwestward from the northwestern corner of Montague County. Southeast of the town of Henrietta, the narrow belt of clastic facies spreads into a broad fan. Northern lobes of the Perrin delta system interfingered with southern lobes of the fan delta system in south-central Clay County. Sediments prograded into this area both from sources in the Ouachita Fold Belt and from the mountains of southern Oklahoma.

Limestone was rarely deposited across the main Henrietta lobe because of the almost continual influx of clastic sediments; minimum compaction of the coarse terrigenous clastics also provided for little subsidence. Slight pauses in deposition occurred, however, since one

Distribution of Henrietta Fan Delta Lobes

The Henrietta fan delta system is named for the town of Henrietta, Texas, in north-central Clay County. It is used to refer to the thick system or wedge of coarse clastic facies deposited in this part of North-Central Texas during Middle and Late Pennsylvanian. The Henrietta fan delta system occurs entirely in the subsurface and, therefore, a detailed interpretation of facies relationships based on surface exposures cannot be made.

Wolf Mountain Formation.--Net sandstone values of the Wolf Mountain Formation (Plate IV) reveal the presence of thick sandstone facies in northern Montague, northern and eastern Clay, southeastern Wichita and northeastern Archer counties, which extend southward from southern Oklahoma. The thick sequence in northern Montague County apparently prograded southward, while two thick lobes of sandstone in northern Clay County trend southwestward. The multistory nature of these massive, terrigenous clastic lobes is readily apparent from the magnitude and close spacing of the contour lines along individual narrow trends. In northern Clay County, net sandstone values for the Wolf Mountain Formation alone locally increase from about 25 feet to almost 500 feet in less than 3 miles. Nowhere does the Perrin delta system display such rapid changes in thickness.

The largest lobe of the Henrietta system prograded southwestward across northern Clay and into Wichita and Archer counties during deposition of the Wolf Mountain Formation. The system bifurcated several times, with smaller sublobes extending southward. The principal thin limestone, approximately equivalent to the Winchell Limestone, extended almost all the way across the lobe (Fig. 26, Section G-G').

Placid Formation.--During deposition of the Placid Formation (Plate VI), small fan delta lobes continued to prograde into northern Montague County. The lobe in northeastern Clay County maintained the same general location, but it was greatly reduced in size. The principal lobe persisted in northern Clay, southeastern Wichita and northeastern Archer counties; its areal distribution remained basically the same as that of the underlying Wolf Mountain Formation.

Colony Creek Formation.--During deposition of the Colony Creek Formation (Plate VIII), small fan delta lobes persisted in northern Montague and northeastern Clay counties at almost the same positions as in underlying formations. The principal lobe, however, prograded some 50 miles farther across the Eastern Shelf, where it deflected around an outer shelf reef-bank buildup in western-central Baylor County. Several lobes developed in Baylor County, some of which extended southward into northern Throckmorton County. Net sandstone values up to 435 feet occur in northwestern and north-central Archer County, where the system was rejuvenated by sediments from late Missourian phases of the Arbuckle Orogeny (Tomlinson and McBee, 1959).

Thick sandstone units of the Henrietta fan delta system in northern Archer and southern Wichita counties are confined principally to the Colony Creek Formation (Fig. 22, Section F-F'). Massive carbonate facies of the Red River carbonate platform in northern Wichita County, unlike the massive carbonate facies of northern Clay County, interfinger with surrounding shales, indicating a contemporaneous depositional relationship.

As the Arbuckle Orogeny progressed, stream gradients and sediment supplies increased. During deposition of the Colony Creek Formation, the Red River carbonate facies were beginning to be divided by southward prograding fan delta wedges; one lobe prograded through northeastern Wichita County between individual carbonate platform areas (Plate VIII). North of the Red River Uplift, in northern Wilbarger County, fan delta lobes built southwestward into the eastern end of the Hardeman Basin during the Missourian Epoch (Plates IV, VI and VIII). Fan delta lobes in the Hardeman Basin reached thicknesses of 100 to 150 feet during deposition of each of the three Canyon formations.

Lithic Characteristics

Electrical logs of Henrietta fan delta facies in northern Clay County (Fig. 29) exhibit profiles that indicate massive, coarse-grained sandstone facies. Coarsening-upward sequences are rare; most individual stratigraphic units display rather sharp bases and tops, characteristic of rapidly deposited clastic sediments. Well samples contain feldspathic sand or arkose, or what is commonly referred to as "granite wash." Edwards (1959) studied thick Missourian coarse clastics on the north side of the Wichita Mountains, along the southern edge of the Anadarko Basin, and reported that, "The term granite wash is applied to a coarse clastic sediment composed primarily of igneous rock fragments ranging in size from silt to boulders, with varying amounts of detrital carbonates and cherts" (p. 142). He further stated that "...subordinate

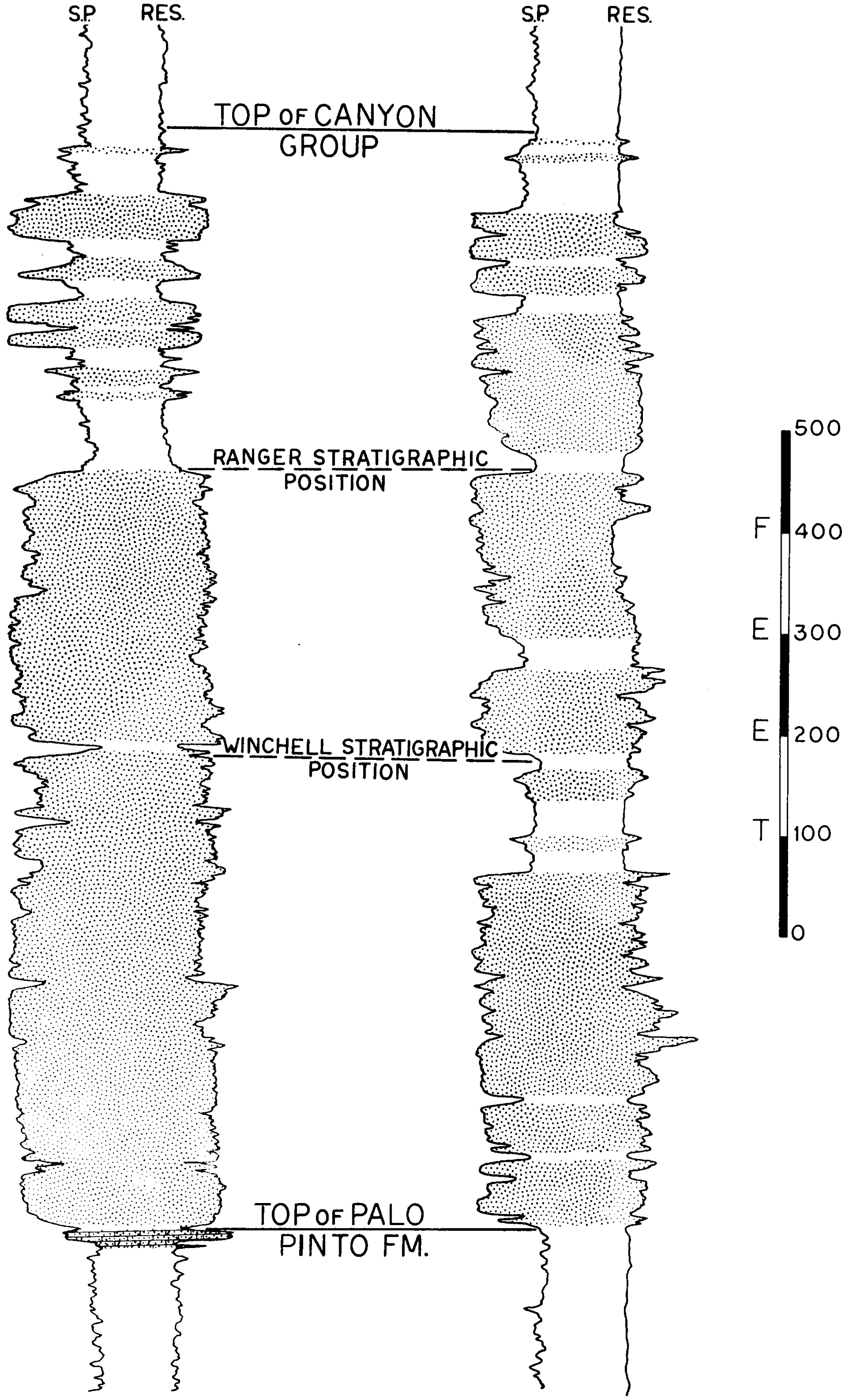


Figure 29. Typical E-log patterns (spontaneous potential and resistivity) through stacked coarse arkosic clastics of a massive Henrietta fan delta lobe; Canyon Group, northern Clay County, Texas.

facies are arkosic sandstones, arenaceous, silty shales, and thin, argillaceous limestones" (p. 150). Compositions of thick clastic sequences of the Henrietta fan delta system are, for the most part, similar to those described by Edwards, based on sample log descriptions.

Henrietta Fan Delta Model

Tomlinson (1929) described the model of the Henrietta system when he interpreted the sequence to be "...gravels, sands and silts of a piedmont alluvial plain bordering the Arbuckle-Wichita mountain system" (p. 73). As the Arbuckle and Wichita Mountain ranges were uplifted during the two basic phases of the Arbuckle Orogeny (late Desmoinesian and late Missourian through Virgilian), thick, coarse-grained fan delta aprons were shed both to the north and to the south (Tomlinson and McBee, 1959). Southward advancing systems filled the relatively shallow Ardmore and Marietta Basins and, in Missourian time, built across the tectonically inactive Muenster Arch into North-Central Texas.

The basin immediately south of the Muenster Arch-Red River Uplift was a northern remnant of the Fort Worth Basin. As sediments of the Henrietta system were introduced from the north, the fault-bounded basin subsided, allowing fan delta wedges to stack in great thicknesses.

By contrast, the Perrin high-constructive delta system to the south prograded over a tectonically stable shelf composed of thick Desmoinesian sediments resting on massive carbonates of the Concho Platform. Subsidence was slow and clastic sediments did not stack to great thicknesses; rather deltas prograded rapidly basinward as a series of relatively thin, shifting lobes. The Perrin delta system was fed by low-gradient streams, which crossed a broad coastal plain immediately west of the Ouachita Mountains. On the other hand, the Henrietta fan delta system was fed by high-gradient (as evidenced by the coarse, poorly-sorted load), probably braided streams, which crossed a relatively narrow, fault-bounded coastal plain composed of stacked wedges of alluvial fan and fan delta sediments.

The principal lobe of the Henrietta fan delta persisted throughout most of Missourian time. The trend of this system must certainly have been controlled by a zone of structural weakness and subsidence south of the Red River Uplift. A structural, probably fault-bounded, low extends southwestward from northern Clay County (Fig. 4). This trough seems to have guided the path along which the principal Henrietta fan delta lobe advanced.

Although distal fan delta facies are subaqueous, much of the Henrietta system was a subaerial deltaic plain. Little carbonate has been recognized within the clastic lobes. Thin coal deposits are associated with the principal Henrietta lobe in north-central Clay, eastern Wichita, northern Baylor and north-central Throckmorton counties.

The depositional framework of the Yallahs Basin area, southeast of Kingston, Jamaica (Fig. 30), is structurally controlled, and the Basin may be fault-bounded (Burke, 1967). Two fan deltas, which are currently prograding into the subsiding basin from the adjacent Port Royal and Dallas Mountains, have built large subaqueous fans extending from the subaerial deltas to the basin floor. Gradients on the fans are high, and sediments include fragments of andesite and granodiorite with

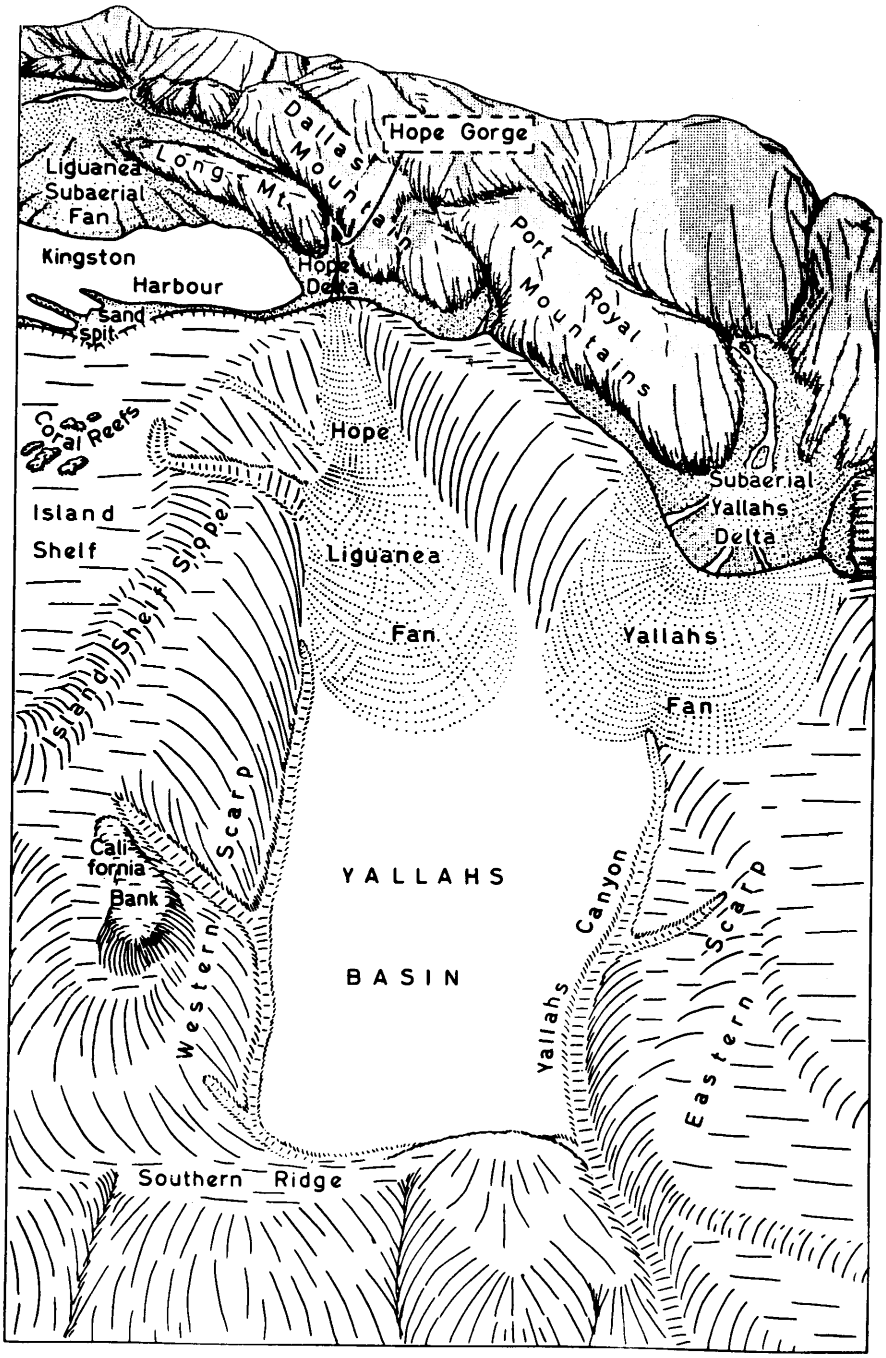


Figure 30. Depositional systems associated with the Yallahs Basin southeast of Kingston, Jamaica; adopted directly from the work of Burke (1967).

a clastic carbonate fraction averaging 30 percent by weight. Along the west side of the Yallahs Basin, a steep scarp supports the California Carbonate Bank and island shelf, which is composed of carbonate detritus with local reefs. Submarine canyons locally cut through this detrital carbonate platform (Burke, 1967).

The Henrietta fan delta system resembles the Yallahs Basin model in some respects. For example, thick wedges of coarse-grained feldspathic sand were deposited in the northern portion of the Fort Worth Basin, fed by nearby sources in the Arbuckle-Wichita Mountains. The Red River carbonate platform lay just to the west and north of the fan system. The Henrietta system, however, did not build across the Muenster Arch and spill over into a 1200 meter deep basin, as do the Yallahs fan deltas. The Henrietta deltas prograded into a relatively shallow, yet subsiding trough. Rates of subsidence in the shallow, tectonically unstable, northern Fort Worth Basin kept pace with, or slightly lagged behind, clastic sediment input, as evidenced by the presence of thin coal beds.

Another large-scale modern fan delta that progrades into a tectonically unstable basin occurs along the northwestern shores of the Gulf of California, with sediment sources in the mountains of Baja, California (Thompson, 1968). Examples of other ancient alluvial fan - fan delta sequences have been described by Mallory (1958), Murray (1958), Allen (1965), Laming (1966), Meckel (1967), Allen and Friend (1968), Klein (1968), Nilsen (1968, 1969), Wilson (1970) and McGowen and Groat (1971).

Carbonate Systems

The Canyon Group was originally defined as a group of thick carbonate units with interstratified shale and sandstone beds that crop out in the Brazos and Colorado River Valleys; the group was easily distinguished from the predominantly terrigenous clastic facies of the underlying Strawn and overlying Cisco Groups. Massive Canyon carbonate units, which crop out in the Brazos River Valley, grade northeastward into deltaic sandstone and mudstone facies of the Trinity Valley area. Sandstone facies of the Perrin delta system prograded westward, at times flanked by depositionally high carbonate banks. As deltaic lobes were abandoned, transgressive shelf carbonate facies blanketed the subsiding deltaic sequences. Henrietta fan delta lobes prograded southward and southwestward, generally in close association with the massive Red River carbonate platform system. On the outer part of the Eastern Shelf, massive reef-bank systems persisted. What was the nature of these Canyon carbonate systems, and how did they relate to the contemporaneous terrigenous clastic systems?

Carbonate Bank Systems

Algal-crinoid carbonate banks developed at various times and in various places during deposition of the Palo Pinto, Winchell, Ranger and Home Creek limestones. A carbonate bank, as defined herein, refers to a skeletal limestone deposit, which stood above the surrounding sea floor with depositional relief. Banks, unlike reefs, are constructed by non-framebuilding organisms, such as marine plants and crinoids, which produce, baffle and trap lime mud and skeletal debris, thus, building up a depositional high. Carbonate bank sequences may contain local patch reefs of corals or bryozoans but, for the most part, the bank systems are biostromes which interfinger with surrounding terrigenous clastic sediments. Carbonate banks of the Canyon Group formed on rather low-energy, shallow-shelf areas on older deltaic sands and muds. Algal carbonate sediments probably accumulated in waters that did not exceed 10 to 15 feet in depth, based on comparisons with recent algal carbonates. Banks were oriented essentially parallel with depositional strike (northeast-southwest); they commonly ranged from 100 to 300 feet thick.

According to Wermund (1966, 1969) and Pollard (1970), the Winchell Limestone is predominantly phylloid algal biomicrudite and biomicrite (terminology after Folk, 1959) with abundant fenestrate bryozoans and local crinoid concentrations. Pollard (1970) found that phylloid algae in the Winchell and other Canyon limestones comprise genera of green algae, including the codiaceans Eugonophyllum, Anchicodium and Ivanovia, as well as the dasycladacean Epimastopora. Coralline red algae of the genus Archeolithophyllum are also present. Wermund (1969) stated that encrusting algae, tentatively identified as Osagia form pellets common in sparry grainstone facies. Phylloid algae grew as erect plants on the sea bottom and trapped lime mud; a variety of other organisms thrived in association with the algae. These included gregarious crinoids, fenestrate and encrusting bryozoa, fusulinids, echinoids, local rugose corals of the genera Lophophyllidium and Caninia, colonial Syringoporid corals, sponges of the genus Heliospongia, brachiopods including the genera Composita, Neospirifer, Echinochoncus, and *Juresania*, gastropods of the genera *Bellerophon* and *Straparolus*, and pelecypods including the genera *Aviculopinna*, *Myalina* and *Culunana* (Wermund, 1969; and observations by the writer). Fusulinids are concentrated in zones up to a few feet thick within micrite matrix material.

Biolithites (true reef rock) are rare in outcropping Canyon carbonate units. Local *Syringopora* buildups occur in the Home Creek Limestone of Jack County and in the Winchell Limestone of the Possum Kingdom area. Perkins (1964) described buildups of the solitary coral *Caninia* in the Home Creek Limestone of Jack County, but these are local biostromal zones and are not true biolithites. Raish (1964) described local bryozoan biolithites in the Chico Ridge Limestone of western Wise County. Micrite and fossiliferous micrite are common in outcropping Canyon carbonate units, as are local, well-winnowed carbonate grainstones, which may be taken as evidence of localized higher energy in the form of waves and currents, possibly due to local shoaling.

Roepke (1970), in studying Canyon carbonates in Brown County, concluded that the abundance of biosparite beds (carbonate grainstone) seems to increase upward in some units, possibly indicative of the buildup of carbonate banks, climaxing with relatively high-energy shoal conditions. Along the Stephens-Palo Pinto County line northwest of Strawn, Texas, the Winchell Limestone is capped by a 6-inch zone of silicified shell debris and by local accumulations of *Myalina*, some of which have both valves intact and exhibit little evidence of transport (see Appendix 1; Measured Section Outside Mapped Area). This zone may represent a relatively high-energy, shoal-water accumulation of shell debris.

Outcropping carbonates of the Canyon Group display irregular and uneven beds, generally less than 1 foot thick; locally beds are up to 3 feet thick. Dense, well indurated limestone beds are intercalated with thin zones of terrigenous sandy mud, derived from nearby deltas.

Wermund (1969) presented four conclusions concerning the origin and development of Canyon carbonate banks. These are as follows: (1) carbonate banks commonly originated on bathymetric highs on the sea floor, such as old deltaic platforms or previously existing carbonate banks or reefs; (2) the maximum and most rapid growth of carbonate banks occurred where phylloid algae and crinoids thrived, namely on shallow, well-lit, non-turbid bottoms; (3) production and entrapment of lime mud by living organisms and accumulation of skeletal debris allowed carbonate banks to build up; and (4) carbonate banks built up above the surrounding sea floor and stood as wave resistant mounds.

Raish (1964) concluded that the Chico Ridge carbonate bank is composed of nine distinct limestone facies, which include poorly fossiliferous calcilutite, algal calcilutite, crinoidal calcilutite, sponge calcilutite, bioclastic calcarenite, oolitic calcarenite, bioclastic calcirudite, fusulinid calcirudite and bryozoan biolithite. Algal calcilutites and calcarenites are the principal facies. Calcarenites are concentrated in beds that dip up to 10 degrees and flank the inner-bank calcilutites. The flanking calcarenites built up slightly higher than the interior bank facies and partially shielded the interior areas from wave and current activity. Raish estimated that the Chico Ridge bank stood 30 to 50 feet above the surrounding sea floor, based on heights of the steeply dipping flank beds. He found no evidence to support a reef origin for the Chico Ridge carbonate bank.

Tongues of coarse carbonate debris (i.e. Rock Hill Limestone) were periodically shed from the Chico Ridge carbonate bank. Zones of sharply angular to rounded carbonate debris are evident in cores of black mudstones lateral to the Chico Ridge system (Appendix 3). Mudstone units immediately below the carbonate debris zones are locally swirled and contorted as if the debris had been rapidly deposited. McGowen (personal communication, 1973) has suggested the existence of carbonate turbidites or debris flows originating on the banks. Such flows could have been generated by storms, which washed carbonate debris over bank edges into deeper water where terrigenous muds were accumulating, under quieter water conditions.

Evidence for depositional relief of Canyon carbonate banks includes: (1) peripheral sloping wedges of oolitic-bioclastic calcarenite described by Raish (1964) for the Chico Ridge Limestone; (2) presence of surface and subsurface tongues of coarse, poorly-sorted and rounded intrasparudite and limestone breccia, such as the Rock Hill Limestone, which were shed as talus debris off the flanks of the shoal-water banks; (3) presence of a high percentage of sparite and grainstone composing the thick, central banks, indicative of shoal water, higher energy conditions (Wermund, 1966); (4) the fact that the final carbonate facies within a bank sequence is generally a grainstone (Wermund, 1966; Roepke, 1970), indicative of the higher energy effects of shoaling; and (5) the fact that granular bank facies in the Possum Kingdom area normally dip up to 10 degrees (Wermund, 1966), suggesting high-energy, perhaps migrating carbonate bars or sand waves. The depositional relief of carbonate banks was probably not due solely to lime mud and skeletal accumulation. Banks may have started forming initially on relatively high, abandoned deltaic platforms. These platforms furnished a stable, shallow, well lighted substrate on which photosynthetic green algae thrived. The algae required shallow depths where there was adequate light penetration. If the water over carbonate banks was intermittently turbid with suspended lime mud, then the depth at which green algae could have lived was severely restricted.

Two continuous cores through parts of the Chico Ridge Limestone of northwestern Wise County were examined (Appendix 3; Plate V: CH2, CH3). Both cores penetrated carbonates on the western (seaward) side of the bank. Core No. 2 is seaward from the bank proper, whereas Core No. 3 is nearer the center of the bank. Core No. 1 (CH1, Plate V), near the landward (eastern) side of the Chico Ridge Bank was available but was not described. Both cores examined contain abundant phylloid algal biomicrudite and crinoid biomicrudite, with numerous intercalated terrigenous mudstone beds. In both cores, the carbonate sequences are capped by relatively thick biomicrudite facies; both cores also contain a single fusulinid zone within the upper biomicrudite units. Core No. 3, nearest to the bank proper, contains several zones of biosparite and intraclastic biosparudite; Core No. 2, which is seaward, contains no biosparite. Several coated-grain and oolite zones occur in Core No. 3; Core No. 2 showed none of these features. Wermund (1966) reported that the bank facies of the Winchell Limestone has a high percentage of sparite (grainstone) relative to the off-bank facies. This higher sparite percentage on elevated banks is probably a result of winnowing of lime mud and concentration of skeletal material by waves and currents on shoal-water areas. Local, shallow cross-bank channels filled with well sorted biosparite have been noted by the writer within the Winchell bank carbonates of the Lake Possum Kingdom area.

Wermund (1969) noted that short tongues of bank facies interfinger laterally with mudstone units on the seaward (western) side of the banks; long tongues of limestone interfinger with mudstone units on the landward (eastern) side of the banks. This relationship occurs in the Chico Ridge Limestone (cross section A-A', Fig. 25). The banks probably restricted lagoonal areas on their landward sides; these protected, lower energy areas may have experienced more prolific algal-crinoid growth and buildup of lime mud and skeletal debris than the higher energy fore-bank zones. In addition, winds, which probably approached from the west (seaward), may have washed skeletal debris and lime mud off of the elevated banks and into the lagoonal areas to the rear; similar to the formation of washover fans on the lagoonal sides of presentday barrier islands. Some Canyon carbonate banks may have been intermittently emergent as evidenced by angular, at least partially prelithified, fossiliferous micrite clasts incorporated in flanking talus deposits.

Carbonate bank systems of the Canyon Group seem to coincide with a structural trend, which ran northeast-southwest through northwestern Palo Pinto, central Stephens, southeastern Shackelford and northeastern Callahan counties (Brown, 1969). This trend may have been a late Desmoinesian-early Missourian axis of tilting or perhaps simply a zone of slow subsidence and relative stability. The Palo Pinto Limestone bank became established along this trend, and later Winchell and

Ranger carbonate banks formed on the stable area. Once formed along the stable structural zone, the carbonate bank influenced the position of later banks by offering a high, slowly subsiding foundation upon which to build. Carbonate banks (notably the Chico Ridge bank) formed on abandoned deltaic sediments.

Cores through the Chico Ridge Limestone (Appendix B) contain zones of black plant debris, which formed by the accumulation of peaty material derived from shallow intertidal-dwelling Pennsylvanian plants that probably occupied ecologic niches similar to modern mangrove swamps of the Florida carbonate banks.

The Winchell and Chico Ridge banks flanked major lobes of the Perrin delta system (Plate V). Areal distribution of the banks is represented generally by thicknesses of limestone greater than 100 feet. Off-bank or transgressive shelf carbonates are generally delineated by limestone thicknesses less than 100 feet. Bank limestones are stratigraphically equivalent to Wolf Mountain Perrin delta facies, whereas transgressive shelf, off-bank carbonate tongues onlapped and, thus, overlie the Wolf Mountain Formation (Figs. 5 and 21).

The southern carbonate bank (Lake Possum Kingdom area, NW Palo Pinto County), which started forming during Winchell deposition, persisted as a bank during deposition of the Placid Formation and remained as a prominent Ranger Limestone bank (Plate VII). The Winchell and Ranger Limestones coalesce in western-central Stephens County, enclosing the Placid deltaic facies to the northeast in a carbonate envelope (Figs. 21 and 22). Thick Ranger bank limestone facies developed in northern Shackelford and western Young counties. The massive Ranger Limestone in western Young County (Plate VII) may have formed on the stable, slightly elevated Bend Arch. An elongate Ranger Limestone buildup in southeastern Archer County is a relatively small bank, which developed on the distal delta-front facies of the abandoned Perrin delta. In northwestern Montague County, over 90 feet of Ranger Limestone was deposited on minor lobes of the Henrietta fan delta system.

The Home Creek Limestone is widespread and discontinuous (Plate IX). Upper Canyon banks developed in southern Shackelford County, and a thick, elongate carbonate unit parallels the major lobe of the Henrietta fan delta system through Throckmorton and Archer counties (Figs. 22 and 25). This thick carbonate trend possibly was not an elevated bank system, but rather may have formed by carbonate accumulation in an embayment lateral to the principal Henrietta fan delta lobe. Home Creek carbonate deposition was contemporaneous with the last phases of Henrietta fan delta deposition.

Transgressive Shelf Carbonate Systems

With abandonment of each of the three major episodes of deltaic progradation (Wolf Mountain, Placid, and Colony Creek), extensive carbonate facies of the Winchell, Ranger and Home Creek Limestones, respectively, onlapped the subsiding delta lobes. In outcrop, these relatively thin carbonate units are similar in composition to the carbonate banks. Phylloid algal biomicrudite predominates, with local concentrations of biosparite and intraclast-rich zones distributed throughout. The widespread shelf carbonate facies are generally 5 to 50 feet thick at outcrop and are irregularly and unevenly bedded.

Individual beds average less than one foot thick and are separated by thin shale beds derived from nearby deltaic sources. In the subsurface, these limestone facies are relatively thin, widespread carbonate deposits (Plates V, VII, IX).

Transgressive shelf carbonate facies of the Winchell Limestone extended outward from the carbonate bank areas after abandonment of the Perrin delta. Winchell shelf carbonate facies, which are up to 85 feet thick, average 50 to 60 feet thick and are distributed over the Perrin delta (Wolf Mountain Formation) in Jack, Young and Throckmorton counties. The Ranger Limestone, which is up to 70 feet thick, but averages 40 to 50 feet thick, transgressed the Perrin delta system (Placid Formation) in Jack and southern Clay counties. The Ranger Limestone is generally thickest where carbonate facies accumulated first in inter-deltaic embayments; as deltaic subsidence progressed, the carbonate onlapped surrounding delta lobes.

Shelf carbonate of the Home Creek Limestone is also thickest in interdeltaic and on open shelf areas (Plate IX). Limestone units are thin over most of the Perrin delta lobes of the Colony Creek Formation of Jack, southern Clay, southeastern Archer, and northeastern Young counties. The Home Creek Limestone, which is 20 to 40 feet thick in those areas, is thickest in interdeltaic areas and over the fringes of delta lobes (Plates VIII and IX).

Transgressive shelf facies of the Home Creek Limestone are thin over the principal Henrietta fan delta lobe (Fig. 22). The Henrietta system remained as a slowly compacting, possibly subaerially exposed, delta for a long period of time, while Home Creek carbonate facies accumulated in adjacent flanking areas.

Red River Carbonate Platform System

During deposition of the Canyon Group, the Red River Uplift persisted as an east-west trending structural high that supported development of a massive platform carbonate sequence in northern Clay, Wichita, and central Wilbarger counties (Plates V, VII and IX). Wells penetrating the Red River carbonate platform indicate that alternating massive limestone and shale sequences commonly reach thicknesses of 2,000 to 3,000 feet in low areas between granitic knobs. Where other wells encountered granite at relatively shallow depths, carbonate facies are commonly only a few hundred feet thick (Figs. 22 and 26). The Red River platform separated the Hardeman Basin of southern Oklahoma and North Texas from the Eastern Shelf-Midland Basin areas throughout Desmoinesian and Missourian times. On the platform, carbonate deposition probably remained near sea level throughout deposition of the Canyon Group; slow subsidence kept pace with limestone accumulation. Intermittently, the area may have been an emergent island or series of islands during Missourian time, but Wermund (personal communication, 1973) has stated that fusulinids of the genus *Triticites* have been found in the upper carbonate units, indicating carbonate accumulation during Missourian time.

During deposition of the Ranger and Home Creek Limestones, thick tongues of limestone spread north and south from the Red River platform in Wilbarger, Baylor and Wichita counties (Plates VII and IX). Massive Home Creek Limestone tongues formed adjacent to upper parts of the principal Henrietta fan delta lobe in Wichita and southern Wilbarger counties (Plate IX). During deposition of the Colony Creek Formation, the eastern end of the Red River carbonate platform was beginning to separate into a series of individual detached carbonate banks (Plate IX).

Carbonate deposition on the Red River platform ceased near the end of Missourian time. By Late Missourian and Early Virgilian times, basins just north of the Red River carbonate platform had been filled by southward prograding feldspathic clastics from the rising Arbuckle and Wichita Mountains (Tomlinson and McBee, 1959). In early Virgilian time (lower part of Cisco Group), thick clastic facies from northern sources overlapped the Red River Uplift in Wichita and Wilbarger counties and spread southward into Texas (Wermund and Jenkins, 1970), probably as a series of fan deltas.

Since rates of recent algal carbonate accumulation are slow compared to rates of delta progradation, the entire Missourian Epoch on the Red River platform may be represented by only a few hundred (perhaps 400 to 500) feet of carbonate rock. The entire Paleozoic section on the Uplift probably did not exceed 3,000 feet in thickness.

Shelf Edge Reef-Bank Systems

During late Desmoinesian (Strawn Group) and Missourian times, carbonate deposition persisted on the developing shelf edge. Similar carbonate deposition persisted locally in eastern-central Baylor County. In these areas, combinations of skeletal bank accumulation and reef growth produced local carbonate buildups, which exceed 1,500 feet in thickness (Figs. 20, 24 and 25). Studies by Wermund and Jenkins (personal communication, 1973) and by numerous petroleum geologists (Conselman, 1960) have documented a trend of Canyon reef-bank carbonate buildups through eastern Haskell, eastern Jones, western Taylor, southeastern Nolan, northeastern Coke and northwestern Runnels counties just to the west of the present study area (Fig. 6). Basinward of this line of carbonate buildups, the Canyon Group thins rapidly and consists primarily of shale with thin, relatively steeply dipping, limestone beds (Fig. 20). Sandstone units of the Canyon Group in western Haskell and eastern Stonewall counties, which lie basinward of the massive reef-bank carbonate system (Fig. 20), may represent slope and basin-edge clastic wedges fed from the Perrin and Henrietta systems to the east. Wermund and Jenkins' (1970) second derivative trend surface maps for the Canyon Group indicate that some of this slope-basin sandstone may have been derived from deltas which prograded southward across the Northern Shelf of the Midland Basin.

The massive shelf-edge carbonate accumulations are interpreted to be a system of banks and local reefs, which persisted throughout deposition of deltaic and shelf carbonate systems to the east. Some of the initial carbonate accumulation began in Late Desmoinesian time (upper part of the Strawn Group) and persisted throughout Missourian time (Fig. 25). The massive carbonate buildups are quite local, with net limestone increasing from a few feet to over 1,200 feet in 1 or 2 miles. Electric log characteristics commonly indicate porous, salt water-saturated carbonate facies. These reef-bank buildups locally produce hydrocarbons (Conselman, 1960).

In five cores representing forebank, bank proper and backbank areas, Toomey and Winland (1973) observed no framebuilding organisms in Desmoinesian shelf-edge limestones of the Nena Lucia Field (Nolan County).

They stated that prolific growth of phylloid algae was responsible for the buildups. Six distinct carbonate facies were identified: (1) crinoidal debris facies, on the outer and upper parts of the mound buildup; (2) pelletal-foraminiferal facies, on the immediate front of the bank; (3) algal-plate facies forming the massive, porous, hydrocarbon productive core of the bank; (4) algal-intraclast facies, in areas beneath and immediately behind the bank core; (5) intraclastic facies, interbedded with other facies; and (6) micrite facies, in the lower part of the algal-intraclast facies. A facies cross section presented by Toomey and Winland (ibid., 1973) indicates that the algal-bank proper built upward and migrated toward the shelf through time.

Myers, Stafford and Burnside (1956) reported that the Late Paleozoic Horseshoe Atoll in the northern part of the Midland Basin is composed largely of fragments of crinoid columnals, bryozoan fronds and brachiopod shells in a matrix of carbonate mud and sparry calcite. Little algal debris was noted and corals are a minor faunal constituent. Oolites are common in local, well sorted calcarenites. Calcarenites (grainstones) are the most abundant textural facies present in the cores studied by Myers, Stafford and Burnside. Calcilutite and calcirudite, in that order, are the next most abundant facies.

These Pennsylvanian carbonate facies examples can be used as comparative models for Canyon Group shelf edge reef-bank systems. All of these systems are massive, abrupt, precipitous accumulations similar to modern coral and red-algal reefs but are composed almost entirely of phylloid algal, crinoidal, and other skeletal debris. Few frame-building organisms are present.

The reef-bank system of the Canyon Group probably began to develop as Late Desmoinesian and Early Missourian algal and crinoid banks on a slightly developed shelf edge, where the break-in-slope was only minimal. The Midland Basin continued to subside, as sediments accumulated on the Eastern Shelf. The shelf edge break-in-slope subsequently became more pronounced, and carbonate growth was stimulated by upwelling, calcium carbonate charged waters from the deepening basin. Algal, crinoid and other associated skeletal debris built up at rapid rates in the clear, freely circulating waters of the outer shelf and basin. Carbonate deposition may have persisted approximately at the prevailing wave base; thus, rigid, frame-building organisms were not required for the banks to remain as stable depositional highs. Only when carbonate accumulations reach and exceed prevailing wave base are rigid frame-builders required for stability. Organisms such as reef-building corals and red algae probably do not survive well below the prevailing wave base, a fact which may help to account for their sparsity in Pennsylvanian reef-bank system rocks.

Shelf edge carbonate systems of the Canyon Group probably acted as partial sediment dams for outbuilding and upbuilding deltaic and shelf systems. By the end of Missourian time, the shelf edge exhibited a well developed break-in-slope, largely due to the stabilizing and damming effects of the massive Canyon reef-bank system. Virgilian (Cisco--Wichita-Albany Groups) clastic systems prograded to the edge of this well defined shelf edge and spilled over as a sequence of thick slope wedges (Galloway and Brown, 1972).

Examples of other studies dealing with Pennsylvanian carbonate rocks include those of Harbaugh (1959, 1960) and contributors to the Kansas Geological Society 27th Field Conference Guidebook (1962).

PALEOECOLOGY

Close relationships exist between various invertebrate faunas and specific sedimentary facies of the Canyon Group. Conclusions drawn here are based exclusively on field observations, but are in general agreement with conclusions drawn by Heuer (1973) in his study of Wolf Mountain Shale faunas of the Lake Possum Kingdom area. Assemblages characteristic of each principal facies or group of associated facies are described and their general paleoecologic significance is evaluated.

Prodelta/Distal Delta-Front Environment

These environments were characterized by rapid, sporadic deposition of fine suspended sediments, which produced turbid water conditions, local turbidites and soft, unstable bottom sediment conditions. Few marine organisms could exist under such conditions; therefore, prodelta and distal delta-front mudstone and thin sandstone units are largely barren of macrofossils. These sediments commonly are laminated, indicating that even non-selective deposit feeders did not thrive. Thin sandstone beds, however, locally exhibit horizontal feeding trails and tracks on lower and upper surfaces. One or two species of small pelecypods, gastropods and conularids occur rarely in prodelta mudstone units. Sparse coiled nautiloids and small crinoid columnals have been noted in distal prodelta and delta-front sequences, along with local inarticulate brachiopods of the genus *Orbiculoidea*. These environments commonly contain abundant fine, carbonaceous plant debris, which was transported from terrestrial environments.

Delta-Front/Distributary Channel Environment

Massive to highly contorted delta-front and distributary channel sandstone facies were deposited rapidly, normally under conditions of pronounced turbulence. As a result, the facies commonly are barren of marine fossils. Some burrowed zones are present, especially near the tops of these units, indicating periods of slack flow with little deposition or sediment transport. During such periods, burrowing organisms colonized the relatively stable sands. Thin, reworked zones may contain fusulinids, crinoidal debris, mollusc fragments, orthocone nautilcids and other organisms, but these zones are rare. Transported terrestrial plant debris is abundant, including stem casts (notably *Calamites*) and leaves up to several inches long.

Delta Plain Environments

Delta plain mudstone and silty mudstone beds locally bear root mottles, but they commonly appear homogeneous. Thin, coaly zones commonly contain abundant plant impressions. Flattened *Calamites* pith casts and delicately lined impressions are very abundant in thin, delta plain coal beds. No invertebrate fossils have been noted in what are interpreted to be delta plain deposits. As previously stated, delta plain deposits are rare, probably due to marine reworking of these originally thin facies after abandonment.

Interdistributary Bay Environment

Shallow bay-lagoon facies between distributaries or overlying abandoned and foundered delta lobes commonly are thin, discontinuous, highly argillaceous limestone units that are platy or nodular. Phylloid algal blades and crinkled, ripped-up algal mat chips and flakes are abundant. The fauna includes crinoid debris, productid and *Composita*-type brachiopods, some *Myalina* valves, echinoid spines and plates and a variety of pelecypods and gastropods.

Interdeltaic Environment

The prolific and varied faunas of open shelf mudstone facies may also be found in interdeltaic areas where detrital sediment influx was relatively limited (see fauna later). Where clastic detrital sediment influx was great, faunas were severely restricted to infaunal sediment ingestors and a few planktonic and nektonic species. Where detrital sedimentation was limited or virtually absent, faunas were prolific and varied, and numbers of individuals were great. Water depth probably was a secondary factor influencing faunal diversity.

Destructional Deltaic (Marine) Sandstone Environment

Thin, highly burrowed, vuggy, reworked sandstone beds, which generally overlie deltaic sequences and underlie shelf carbonate units, contain abundant vertical and horizontal branching burrows up to one inch in diameter. Large *Myalina* shells and brachiopods occur in some of the sandstone beds; rarely are both valves of *Myalina* intact. *Myalina* is associated with reworked and redistributed facies, including tidal channels filled with both clastic and carbonate sediment. Reworked sandstone units may contain abundant fusulinids and shell debris.

Open Shelf Environment

By far the most prolific and diverse invertebrate faunas are found in open shelf mudstone, which was deposited on abandoned delta facies and overlapped by shelf carbonate units. Brachiopods of many varieties are abundant; gastropods are also abundant; and crinoid debris is common. Corals of the genus *Lophophyllidium*, fenestrate and encrusting bryozoa, fusulinids, orthocone nautiloids, coiled nautiloids and goniatites, sponges, echinoid spines and plates, scaphapods and a few species of pelecypods are common faunal constituents within open shelf mudstone facies. The dominance of filter-feeding brachiopods and crinoids may be indicative of relatively non-turbid water conditions, distant from terrigenous sediment sources. Fusulinids occur in great abundance in marly mudstone facies below shelf carbonate units and within the carbonate sequences themselves. As previously mentioned, the prolific faunas of open shelf environments are also found in the mudstones which were deposited in broad interdeltaic embayments, away from centers of rapid clastic deposition.

Prolific sponge faunas occur immediately below many onlapping shelf carbonate units and lateral to carbonate bank facies. Several varieties of sponges thrived together. Crinoid debris is associated with the prolific sponge faunas, but corals are virtually absent from dominantly sponge communities. Sparse corals and sponges may occur together, but abundant sponges and corals rarely occur together. Competition may have existed between these groups for available firm larval attachment sites.

Carbonate Environments

Faunal community structure in the various carbonate facies is complex and was probably influenced by a variety of factors, including water depth, energy, dominance of organisms (local phylloid algal thickets and crinoid thickets supported diverse assemblages), circulation, light penetration, frequency and amount of detrital influx, and many other interrelated variables.

Crinoids seem to have flourished in carbonate areas following periods of silty detrital influx. Crinoidal debris is most common in the silty beds between well indurated limestone beds. Some of the more common carbonate faunal constituents have been mentioned in discussions of carbonate systems.

DEPOSITIONAL SYSTEMS AND ENERGY RESOURCES

Oil, gas and coal have long been produced from Pennsylvanian rocks in North-Central Texas. The distribution of oil and gas accumulations is complexly related to primary depositional framework, regional and local structure, time of structural movement, sediment diagenesis, and proximity to outcrop. Coal deposits are related almost exclusively to primary depositional framework. Information dealing with locations of Canyon Group hydrocarbon-producing fields comes from the work of Wermund, Jenkins and Ohlen (personal communication, 1973). Information on subsurface distributions of Canyon Group coals is based on the work of Mapel (1967).

Oil and Gas

Unlike the Strawn and Cisco Groups, the Canyon Group in the area studied is relatively non-productive of oil and gas, especially from sandstone facies. Sandstone units of the Perrin delta system, even though well developed and associated with thick prodelta source beds, are non-productive. One small field produces from deltaic sandstones within the Palo Pinto Limestone interval of southeastern Archer County (Fig. 31).

The only significant hydrocarbon production from sandstone facies is in fields in southern Wichita and northern Archer counties, along the northwestern flank of the principal Henrietta fan delta lobe. The two Wichita County fields produce from thin channel sandstone reservoirs in the Wolf Mountain Formation, whereas northern Archer County

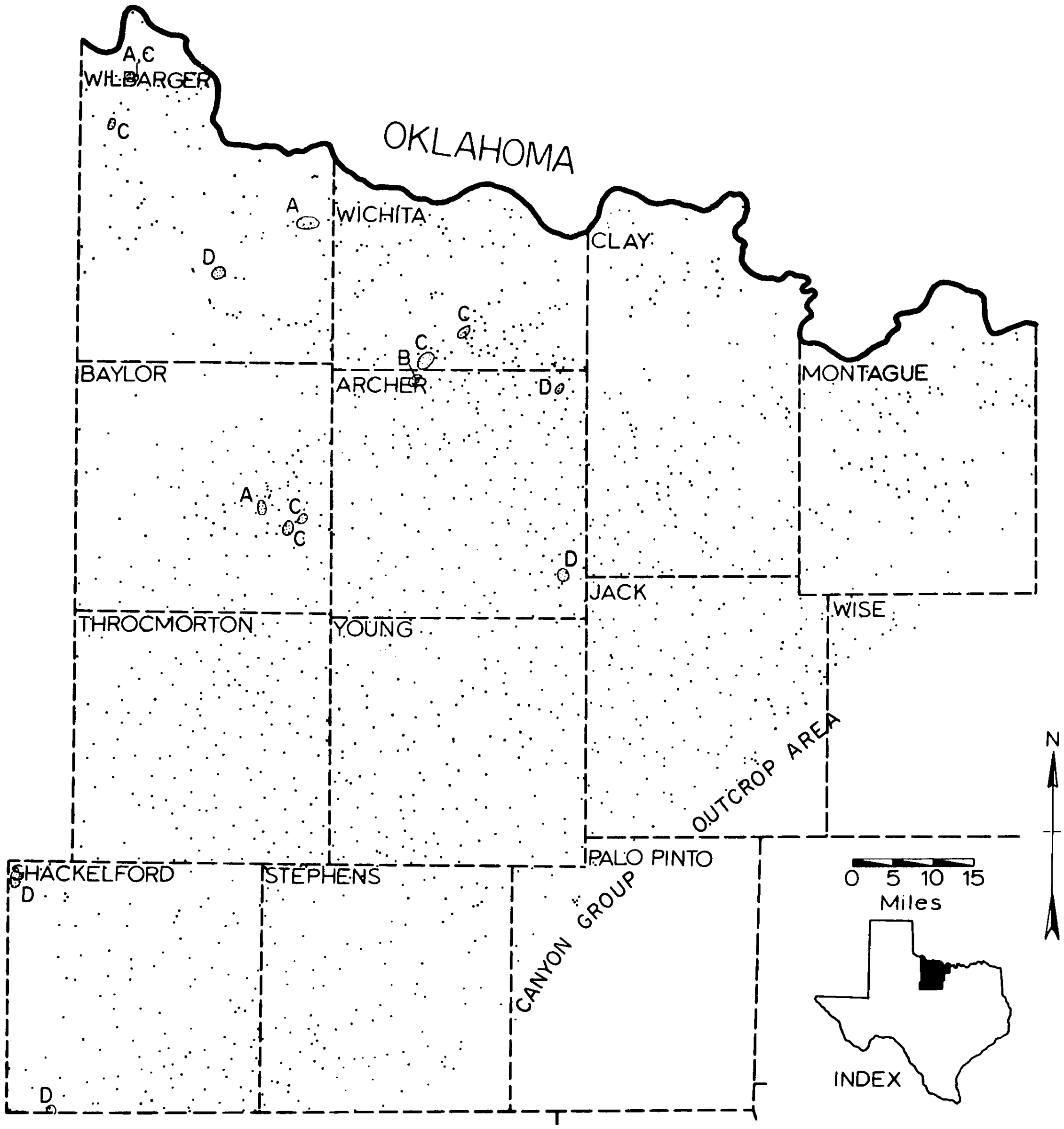


Figure 31. Distribution of hydrocarbon production from the Canyon Group, North-Central Texas. Adapted from unpublished studies by E. G. Wermund and W. A. Jenkins (personal communication); letters refer to Canyon interval from which production comes: A. Home Creek Formation B. Colony Creek Formation C. Wolf Mountain Formation D. Palo Pinto Formation

production is from thicker sandstone reservoirs of the Henrietta system (Colony Creek Formation). A small field in northern Wilbarger County produces from thin sandstone reservoirs within the Home Creek Limestone. Small fields in northeastern Archer and southwestern Shackelford counties produce from thin sandstone beds within the Palo Pinto Limestone.

Tomlinson and McBee (1959) reported that Missourian feldspathic sandstone and conglomerate facies of southern Oklahoma are highly productive. Massive feldspathic facies of the Henrietta fan delta system of North Texas may have further development potential.

Oil and gas production from carbonate systems of the Canyon Group is concentrated in massive limestone units of the Red River carbonate platform and the outer shelf and shelf edge reef-bank systems. Two fields in central and eastern Wilbarger County produce from massive Missourian carbonate facies of the Red River Uplift. Three small fields produce from Missourian carbonate reservoirs in and associated with the massive reef-bank accumulation of eastern Baylor County. One field in northwestern Shackelford County produces from carbonate beds of the Missourian shelf edge reef-bank system, which trends northeast-southwest through that area. The only other hydrocarbons produced from carbonate rocks of the North Texas Canyon Group come from small fields in northern Wilbarger County (eastern Hardeman Basin area).

Coal

Outcropping coals of the Canyon Group are rare and of local areal extent. Two examples of outcropping coals, the Bridgeport Coal and the Dalton Coal, have been discussed. Mapel (1967) mapped the subsurface distributions of coals using approximately 175 sample logs within the present study area. The major coal units lie immediately down-dip from outcrops of the Perrin delta system in Jack, Wise and Montague counties, and on top of delta lobes in northwestern Jack, northeastern Young, southeastern Archer and southern Clay counties (Fig. 32). Two areas of coal concentration are associated with the principal Henrietta fan delta lobe in northern Clay and eastern Wichita counties; coal in the northeastern corner of Montague County is associated with minor lobes of the Henrietta fan delta. Coals in northern Baylor and northern Throckmorton counties are associated with relatively thin, distal sandstone facies of the Henrietta fan delta (Colony Creek Formation). Local coal beds of northwestern Young and northern Stephens counties are associated with Perrin delta lobes. A coal bed in northwestern Stephens, northeastern Shackelford and southeastern Throckmorton counties is related to these same systems. Coal of southwestern Shackelford County may not be related to deltaic sandstone delineated in this study; however, a thin, strike-oriented sandstone body does lie in close association with these coals in the Placid Formation.

Coal units mapped by Mapel (1967) within the area of this study are the major Canyon Group coals mapped for the entire North-Central Texas region, except for coal zones in Hall and Motley counties to the northwest. These northwestern coals are probably associated with feldspathic fan delta sequences, which prograded southward from the Wichita Mountains of southern Oklahoma. The only other coals of the

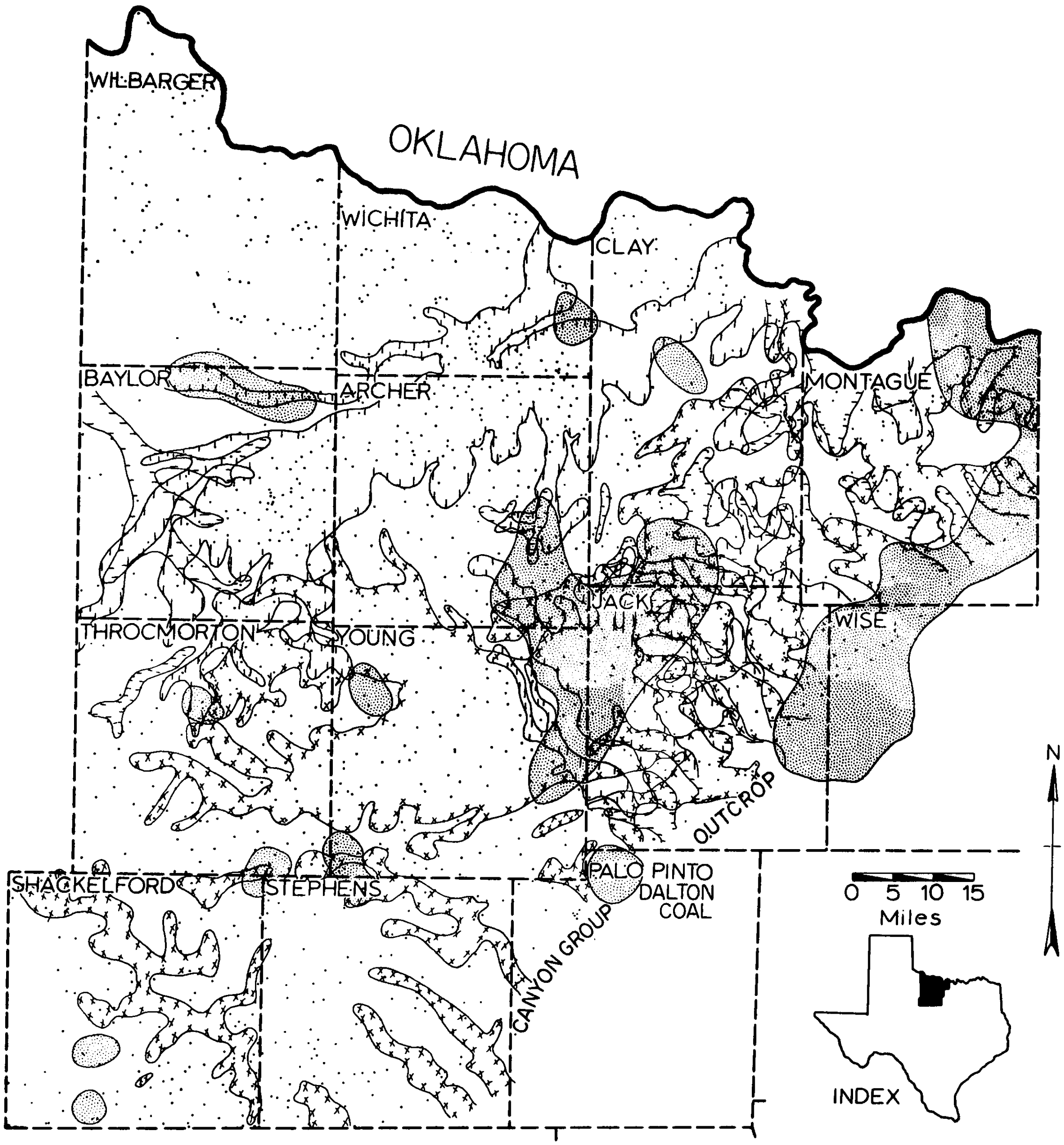


Figure 32. Distribution of Canyon Group coal, from Mapel (1967), with Perrin and Henrietta system lobes superimposed to show the correlation between coal accumulation and deltaic deposition; coals appear as stippled areas.

Canyon Group in North-Central Texas are minor deposits in southern Callahan and northeastern Taylor counties, to the southwest of the study area; these coal beds may be associated with northwestward trending minor delta lobes, which prograded basinward through northern Brown County; as evidenced by outcropping deltaic sandstone facies in the Lake Brownwood area.

SUMMARY AND CONCLUSIONS

The Canyon Group of Missourian age is a sequence of westward dipping carbonate and terrigenous clastic facies, which crop out in a northeast-southwest trending belt across North-Central Texas. At outcrop, thick algal bank and transgressive shelf carbonate systems to the southwest interfinger with and overlie thick, deltaic sandstone and mudstone facies to the northeast in Jack and Wise counties. The high-constructive Perrin delta system prograded westward and northwestward across the Eastern Shelf, to deposit a series of thick, elongate and bifurcating lobes, which are preserved in Jack, Clay, Archer, Young, Baylor and Throckmorton counties. Sources of Perrin deltaic sediments lay in the Ouachita Fold Belt to the east. Three major phases of deltaic progradation are present, in the Wolf Mountain, Placid and Colony Creek Formations. After each major progradational phase, highly fossiliferous, open-shelf muds and superposed shelf carbonate deposits onlapped the abandoned and subsiding delta lobes (Fig. 33).

The Perrin delta system (Wolf Mountain Formation) prograded basinward between the Chico Ridge carbonate bank of Wise and Montague counties and the Winchell carbonate bank of Palo Pinto, Stephens and Shackelford counties. These banks were constructed on top of minor delta lobes of the Perrin system by deposition of phylloid algae, crinoids and other organisms in a carbonate mud matrix. Upon abandonment, shelf carbonate tongues (Winchell and Devil's Den Limestones) spread outward from the carbonate banks and partially onlapped the foundered delta lobes. These transgressive carbonate facies, however, did not spread completely across southeastern Jack County because of continued

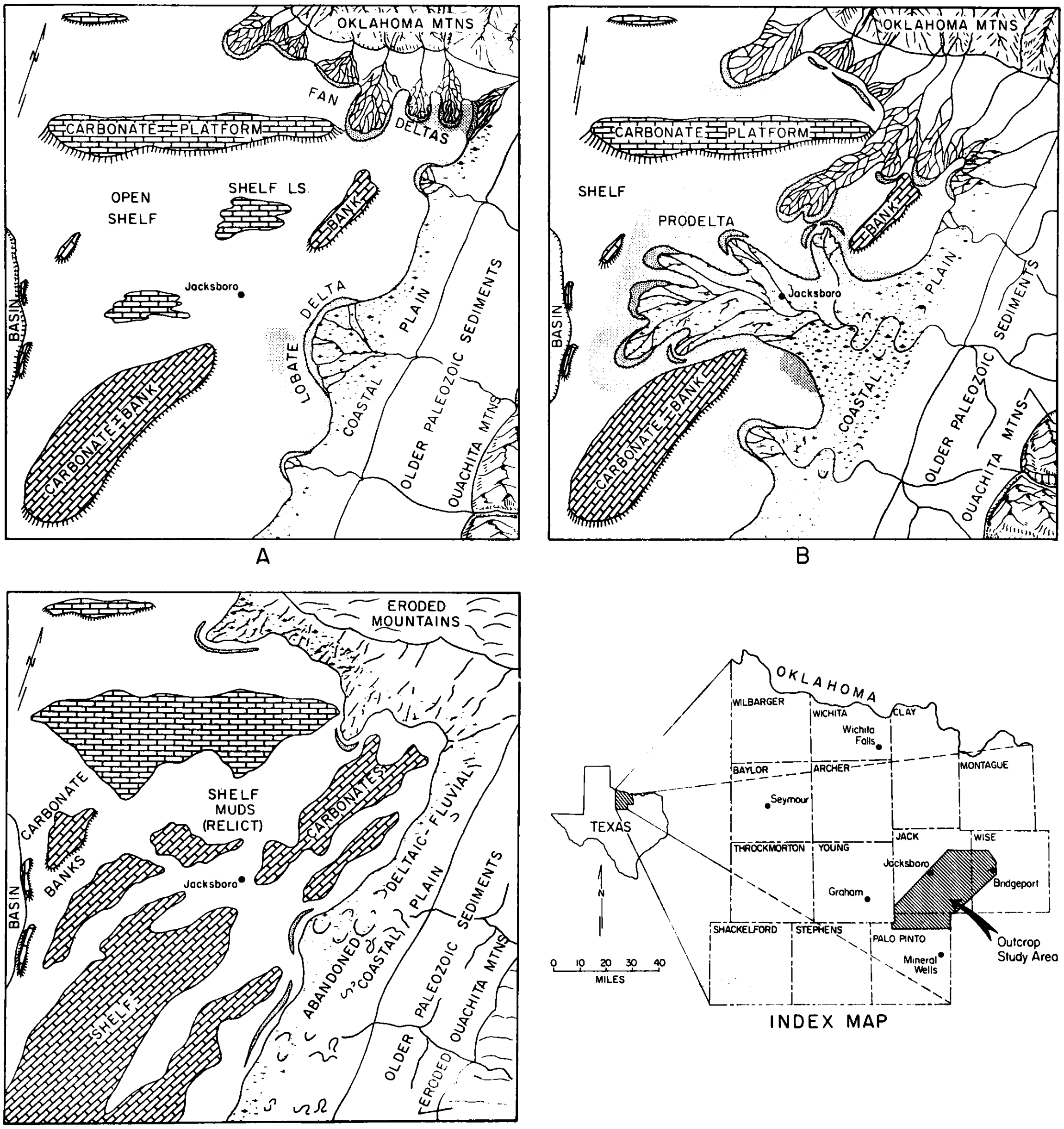


Figure 33. Evolution of Canyon Group paleogeography: A. Early progradation of delta systems B. Maximum extent of delta development C. Transgression of abandoned deltaic lobes and deposition of blanket shelf carbonates. Based on three Canyon delta cycles.

minor deltaic progradation and reworking of older deltaic sediments in that area.

The Perrin delta system (Placid Formation) prograded toward the northwest and west over Winchell Limestone. Outcropping Perrin delta facies (Placid Formation) of eastern Jack and western Wise counties include contorted bar-finger sandstone facies and well developed distributary channel and delta-front sandstone units overlying thick, laminated prodelta and distal delta-front mudstone sequences. A carbonate bank system persisted in Stephens and Shackelford counties, contemporaneous with deltaic progradation.

As the Perrin delta system was again abandoned, transgressive Ranger shelf limestone facies spread northward from the carbonate bank and eastward from the open shelf, onlapping the subsiding delta lobes. Because interdeltaic and interdistributary areas were bathymetrically low and were inundated longest, shelf carbonate units accumulated to greater thicknesses in those areas than on the prominent delta platforms.

Perrin delta lobes (Colony Creek Formation) eventually prograded over shelf carbonate facies for the third time. Coarse-grained fluvial systems locally overrode and eroded finer delta sandstone and mudstone facies in southern Jack County. Strike-oriented barrier island or strand-plain sandstone units up to 100 feet thick, which occur exclusively in the subsurface, are stratigraphically equivalent to the Perrin delta system of Throckmorton, Young, Stephens and Shackelford counties. Upon abandonment of the Perrin delta system, the Home Creek Limestone transgressed deltaic facies.

An idealized sequence of Perrin delta facies demonstrates a constructional and a destructional phase. The constructional sequence, in ascending order, includes: (1) laminated, largely unfossiliferous, prodelta mudstone, containing abundant, fine organic debris and ferrugenous claystone nodules; (2) thin bedded, graded, commonly contorted, fine-grained distal delta-front sandstone and siltstone within laminated shale; (3) fine-grained, plant-rich, massive, proximal delta-front sandstone, which may be heavily contorted and contemporaneously faulted; (4) massive, fine- to medium-grained distributary channel-fill sandstone, which contains trough cross stratification, local clay-chip conglomerate, and abundant plant stems and leaves; and (5) thin, generally coaly, sandy mudstone delta plain units, which commonly appear homogenous and may locally be cut by symmetrical tidal channels. Destructional and transgressive marine facies, which developed on top of abandoned deltaic sequences include: (1) highly burrowed, vuggy fine-grained sandstone beds up to 6 feet thick, which locally contain Myalina shells; (2) heavily bioturbated, fossiliferous mudstone; (3) highly fossiliferous, open-shelf mudstone facies, with abundant brachiopods, gastropods, sponges, crinoids, corals and other organisms; and (4) algal shelf carbonate facies.

The Henrietta fan delta system comprises a series of coarse, feldspathic clastic lobes, which prograded into North-Central Texas from sources in the Arbuckle-Wichita Mountains of southern Oklahoma. The principal Henrietta lobe prograded southwestward through Clay, Wichita, Archer, Baylor and Throckmorton counties. The Henrietta system prograded into a northern remnant of the Fort Worth Basin, where coarse clastic sediments locally stacked to thickness of several hundred feet. The last progradational episode (Colony Creek Formation) resulted from renewed

Late Missourian phases of the Arbuckle Orogeny. Coarse fan delta sandstone facies deflected around a massive, outer shelf reef-bank limestone accumulation in eastern Baylor County. The contemporaneity of the Henrietta fan delta and Perrin high-constructive delta systems is uncertain, but the deposits appear to be stratigraphically equivalent. The Henrietta system is restricted to the subsurface in Texas.

Carbonate systems of the Canyon Group include carbonate banks; a structurally controlled, massive carbonate platform (Red River Uplift); outer shelf and shelf edge reef-bank accumulations; and relatively thin, transgressive shelf carbonate units, which onlapped abandoned delta lobes and open shelf mudstone facies. Carbonate facies are dominantly phylloid algal biomicrudite, with abundant biosparite and intraclastic zones, indicative of local shoaling. Tongues of angular carbonate breccia, such as the Rock Hill Limestone, were periodically shed from elevated carbonate banks.

Faunas of the Canyon Group are related to the depositional environments. The principal factor which governed the number and kinds of organisms in an area was probably the local rate of clastic sediment input. Water depths and salinities were probably secondary factors.

Hydrocarbons are produced primarily from thin sandstone reservoirs peripheral to the principal Henrietta fan delta lobe and from carbonate systems, including the Red River carbonate platform and outer shelf reef-bank systems.

Coals of the outcropping Canyon Group include local subbituminous deposits and transported, argillaceous, fissile coals deposited in bay-lagoon areas. Coals are associated with lobes of the Perrin delta and, to a lesser extent, with Henrietta fan delta lobes.

APPENDICES

APPENDIX 1

MEASURED SECTIONS IN CANYON GROUP ROCKS OF JACK, WISE, AND PALO PINTO COUNTIES, TEXAS

(Refer to Plate I for locations and Plates II and III for graphic presentations and facies interpretations)

Section 1 - (See Figure 10 and Plate III)

	Thickness in Feet
Measured from pond on south side of Hwy. 24, 3 miles west of Vineyard, Texas, westward up road to top of lowest Ranger Limestone member.	
18. Limestone, light gray, phylloid algal-crinoid biomicrudite and biosparudite; unevenly bedded, relatively massive near base, thinner bedded near top; crinoids, fusulinids, brachiopods abundant; very well indurated; Ranger Limestone member	13.0
17. Silty shale, gray to buff, local thin sandstone and siltstone beds; small flow-rolls, local crinoid debris	18.0
16. Limestone, reddish to gray, platy phylloid algal blades and articulated brachiopods; abundant terrigenous sediment intermixed, locally a phylloid algal biosparudite, poorly indurated and flaky	1.0
15. Shale, buff to gray, locally bioturbated; unfossiliferous	2.0
14. Sandstone, buff to reddish, fine to medium gr.; massive, local medium scale trough cross stratification, local burrow clusters with individual burrow fills 0.75 inch in diameter, local plant debris, local clay-chip conglomerate; sand generally clean and well sorted; base appears scoured into underlying units; mud filled channel cutout within this unit	12.0
13. Shale, gray, silty, laminated to homogenous; locally cut out by overlying sandstone	2.0

APPENDIX 1 (Contd.)

	Thickness in Feet
12. Sandstone, buff, silty, fine to very fine gr.; beds 0.5 to 2 ft. thick, base abrupt with numerous load casts and squeezed and contorted sand rolls; abundant horizontal tracks and trails on base; silt beds common in lower 4.5 ft., horizontal laminae and local low angle trough cross stratification predominant in lower 4.5 ft.; small to medium trough cross stratification and horizontal laminations predominant in upper 7 ft.; local concentrations of 1mm. siderite concretions; local burrows near top up to 0.75 inch in diameter	12.0
11. Shale, dark gray to black, silty; thickens westward and contains three sandstone beds; shale is laminated to homogeneous, abundant small sandy concretions, sandy burrow fills common; very fine gr. silty sandstone beds are 4 to 10 inches thick and are rich in horizontal trails and tracks, horizontal laminae, trough cross stratification, abundant black plant hash, one sandstone unit contains small scale trough cross stratification, upper sandstone unit is trough cross stratification with various sole marks on under surface; local burrows in upper unit	4.0
10. Sandstone, buff, fine to very fine gr.; medium gr. near top, base is rolled and contorted, and locally squeezed down into underlying shale; plant debris abundant; sandstone sedimentation units up to 3.5 feet thick, horizontal laminae abundant throughout, local small trough cross stratification more common in upper part of unit; silty, shaly beds up to 6 inches thick have been locally squeezed by overlying sand units; massive sandstone unit near top is 7 to 8 feet thick and is fine to medium gr. with fine clay flakes and chips, well sorted, clean, massive to horizontally laminated, local small trough cross stratification; upper 2 ft. alternating fine sandstone and shale, sand beds show ripple laminae and small scale trough cross stratification throughout, horizontal trails and tracks common; sand beds contain local clay chips up to pea size; thin silty shales are well laminated	11.0

APPENDIX 1 (Contd.)

	Thickness in Feet
9. Shale, dark gray to black, laminated; locally disrupted by loading of overlying sandstone; local black plant debris, local sandstone lenses; no fossils noted	4.0
8. Sandstone and sandy shale, buff to dark gray; sandstone beds up to 2 ft. thick, sand is fine to very fine gr. and contains abundant plant debris; lower sandstone units show ripple laminae, local trails and tracks along bedding surfaces, ripples common on some bedding surfaces; sandstone sedimentation units separated by sandy shales rich in plant debris; uppermost sandstone unit is 2 ft. thick and is horizontally laminated, large woody debris noted here; <u>Calamites</u> pith casts, possible local burrows near top; entire unit broken up westward; beds are locally squeezed down into the underlying shale in the form of contorted sandstone rolls up to 3 ft. across, these are very rich in plant debris; locally unit 6 was eroded into underlying shale, and scours are very rich in black plant debris; almost a coal locally	8.0
7. Shale, dark gray to black, silty, well laminated; abundant ferrugenous silty laminae, thin sandy and silty beds increase upward, thin sandy layers show small ripple laminae overlying horizontal laminae; unit rich in black plant debris; local silty lenses or pods throughout, unfossiliferous; thin sandstone beds are very fine sand and silt with horizontal laminae and local current ripple cross stratification, these appear turbidite-like and are plant-rich; local load and flute casts; upper 10 feet of unit contains squeezed and contorted sandstone rolls up to 3 ft. or more across that appear to be injection structures from the overlying sandstone, these contain abundant plant debris	28.0
6. Sandstone, buff, fine to very fine gr.; base gradational with underlying shale, thin beds below, upper sandstone units contain trough cross stratification up to 8 inches deep; uppermost thin sandstone bed shows ripple laminae; some plant debris	3.0
5. Shale, buff, silty, laminated; abundant reddish ferrugenous claystone nodules; abundant thin ferrugenous silty laminae	6.0

APPENDIX 1 (Contd.)

		Thickness in Feet
4.	Sandstone, buff, fine gr.; thin bedded to flaggy, ripple laminae throughout, local tracks and trails on bedding surfaces, gradational with overlying unit	4.0
3.	Shale, gray to buff, silty; abundant thin silt laminae throughout, largely covered	4.0
2.	Sandstone, reddish to buff, fine gr.; weathering out as massive, squeezed and contorted boulders; sand relatively clean and well sorted; poorly exposed; appears locally scoured	55.0
1.	Sandstone and shale, gray to buff, thin flaggy fine gr. sandstone beds in shale; sandstone beds are horizontally laminated with hints of ripple laminae; shales are silty and laminated; poorly exposed	15.0
	Total	199.0 ft.

Section 2 - (See Figure 13)

Measured along Hwy. 1156, 2 miles west of Wizard Wells, Texas, from base of hill up winding curve to base of lowest Ranger Limestone member at top of hill.

11.	Limestone, light gray, phylloid algal-crinoid biomicrudite and biosparudite; unevenly bedded, fossiliferous, poorly exposed	not measured
10.	Sandstone and sandy shale; thin, flaggy sandstone and siltstone beds in sandy, silty shale; locally well indurated with calcite cement, local calcareous zones; mostly covered	30 +/-
9.	Sandstone, buff to reddish, fine to medium gr., coarse gr. near base; massive in appearance, no sedimentary structures noted, possibly large trough cross stratification throughout entire unit, possible contorted areas, local plant debris, large <u>Calamites</u> pith cast near base, appears to be a channel unit	16.0

APPENDIX 1 (Contd.)

		Thickness in Feet
8.	Silty shale, buff, abundant silt and fine sand beds; percentage of coarser sediment increases upward, unfossiliferous; mostly covered	8.0
7.	Sandstone, buff, fine gr.; beds 1 ft. thick show small scale trough cross stratification; upper 2 ft. highly burrowed spongy or vuggy sandstone with fusulinids, crinoid debris, mollusk hash, and orthocone nautiloids	7.5
6.	Covered; probably thin, flaggy sandstone and siltstone beds in shale; local ferrugenous concretions	13.0
5.	Covered; probably thick fine-grained sandstone beds in silty shale	35.0
4.	Sandstone, buff, fine to medium gr.; a complex of large scoured-and-filled channel-like units, lens-like bars and contorted and loaded sandstone; locally massive, thin bedded near top; complex scour-and-fill patterns, local penecontemporaneous faults; horizontal laminae common filling large troughs, local plant debris, appears locally burrowed, sand well sorted, grades laterally toward the east into thin bedded fine to very fine sandstone	48.0
3.	Sandy shale, buff, thin beds of fine gr. sandstone in silty, sandy shale; unfossiliferous	8.0
2.	Sandstone, buff, fine gr.; large scale trough cross stratification, large lens-like sand units; beds up to 5 ft. thick, local plant debris; well sorted	17.0
1.	Silty, sandy shale, buff, abundant ferrugenous silty partings; appears well laminated, mostly unfossiliferous, local tracks and trails on thin silty, sandy beds; silty, sandy beds increase upward, local fine plant debris, ferrugenous nodules common	58.0
	Total	240.5 ft.

APPENDIX 1 (Contd.)

Section 3

	Thickness in Feet
Measured from creek level in Bear Hollow, eastward up boulder strewn hillslope; continues up knoll 0.4 mile to the north, which is capped by Ranger Limestone float--2.3 miles north of Wizard Wells, Texas.	
8. Sandstone, buff, fine gr.; thin bedded, horizontal laminae, local ripple cross stratification	4.0
7. Silty, calcareous shale, gray to buff; bioturbated, local crinoid debris	7.0
6. Sandstone, buff, fine gr.; thin bedded, burrowed, local ripple bed forms, locally well cemented by calcite	2.0
5. Shale, silty, buff, local calcareous zones; bioturbated	15.0
4. Sandstone, calcareous, gray to buff; thin bedded, burrowed, rippled cross stratification, locally well indurated	4.0
3. Shale, silty, gray; local thin sandstone and siltstone beds; mostly covered	20.0
2. Sandstone, buff, fine gr.; squeezed and contorted boulders the size of small houses weathering out of hillside; sandstone is well sorted with local plant debris, may be more than one sandstone unit present, probably local trough cross stratification; poorly exposed	100 +/-
1. Silty, sandy shale, buff to gray; abundant ferruginous nodules, thin sandstone beds increase in number upward; upper 30 ft. is thin flaggy sandstone beds in silty shale; unfossiliferous	60.0
Total	212.0 ft.

Section 4

Measured from road level along unpaved county road (2.7 miles north of Wizard Wells, Texas), northwestward to top of hill.

APPENDIX 1 (Contd.)

	Thickness in Feet
6. Sandstone, buff, fine gr.; beds up to 3 ft. thick, weathers out in massive boulders which appear squeezed and contorted; mostly horizontal laminae, local trough cross stratification, base appears abrupt and is probably scoured	22.0
5. Sandy shale, buff, fine gr.; sandstone beds common up to two inches thick; some tracks and trails on sandstone surfaces; mostly covered	40.0
4. Sandstone, buff, fine gr.; beds up to 1 ft. thick, horizontal laminae predominant	4.0
3. Sandy shale, buff, sparse beds up to 1 in. thick of fine to very fine sandstone; laminated	7.0
2. Sandstone, buff to reddish, fine gr.; massive boulders appear squeezed, and contorted and show trough cross stratification; sandstone shows lensing and may be channel shaped	17.5
1. Sandy, silty shale, buff; abundant thin sandstone beds and silt laminae; ferrugenous nodules common; unfossiliferous	99 +/-
Total	189.5 ft.

Section 5

Measured westward up high-voltage line right-of-way from road level; off of county road 5.2 miles southeast of Cundiff, Texas.

9. Conglomerate, reddish to gray to white; contains local medium to coarse gr. sandstone lenses, pebbles are chert and other mineral fragments up to 0.5 in. in diameter, silica cement; part of basal Cretaceous gravel complex	10.0
8. Covered; probably sandy shale	6.0
7. Sandstone, buff, fine gr.; boulders appear massive to trough crossbedded and contorted; some portions appear wildly squeezed and contorted; sand well sorted	49 +/-
6. Covered; appears to be shale with thin sandstone and siltstone beds	14.0

APPENDIX 1 (Contd.)

		Thickness in Feet
5.	Covered	27.0
4.	Sandstone, buff, medium to coarse gr.; appears massive to somewhat contorted, large scale trough cross stratification, local conglomeratic concentrations in scours; appears channel like	5.5
3.	Sandy shale, buff to gray; thin, fine gr. sandstone beds in shale; mostly covered	5.5
2.	Sandstone, buff, fine gr.; massive in appearance and locally squeezed and contorted, large trough cross stratification predominant; well sorted . . .	33.0
1.	Sandy, silty shale, gray to buff; thin, fine- to very fine-gr. sandstone beds in silty shale; mostly covered	17.0
	Total	167.0 ft.

Section 6

Measured northwestward up county road from the level of Pecan Branch through the lowest Ranger Limestone member; 5.1 miles east-southeast of Cundiff, Texas.

10.	Limestone, gray, phylloid algal biosparudite and biomicrudite; uneven beds 2 to 6 in. thick; local fusulinid-rich zones, no crinoids or other megafossils noted; Ranger Limestone	8 +/-
9.	Marl, silty, buff; calcareous zones and nodules abundant; appears bioturbated	2.0
8.	Limestone, gray, biosparudite; uneven, thin beds, abundant woody plant debris near base; lowest Ranger Limestone member	5.0
7.	Shale, calcareous, gray; limestone beds and lenses 1 in. thick, more prevalent toward top of unit; no megafossils noted, locally marly to calichefied . .	5.5
6.	Sandstone, buff, fine gr.; beds uneven, up to 4 ft. thick; massive in appearance, hints of trough cross stratification; probably a channel unit	7.0

APPENDIX 1 (Contd.)

		Thickness in Feet
5.	Silty, sandy shale, gray to buff to purple; local thin, fine gr. sandstone beds up to 8 in. thick; ferrugenous nodules common but not abundant; local thin, calcareous zones and streaks; thin sandstone beds more numerous toward top; no megafossils noted	40.0
4.	Sandstone, buff, fine gr.; massive in appearance, no sedimentary structures evident, may contain local trough cross stratification; poorly exposed . .	8 +/-
3.	Sandy, silty shale, gray to buff; thin, fine gr. sandstone beds common; mostly covered	7.0
2.	Sandstone, buff, medium to coarse gr.; trough cross stratification abundant; local conglomeratic zones with clay chips common in lower 8 ft., local ferrugenous nodules and chert pebbles up to 1 in. across; upper 15 ft. of sandstone contains fewer conglomeratic zones and is fine to medium gr.	33.0
1.	Silty shale, buff to gray; mostly covered	8.0
	Total	123.5 ft.

Section 7

Measured southward up county road from 20 ft. above bed of Big Creek; 1.4 miles south of refinery and 5.5 miles west of Chico, Texas.

6.	Conglomerate, reddish to gray; chert pebbles and medium- to coarse gr. sandstone matrix, medium to large scale trough cross stratification throughout; scoured into underlying unit	18 +/-
5.	Sandstone, buff, fine to medium gr.; appears massive; possible trough cross stratification	10.0
4.	Silty, sandy shale, buff to gray; thin sandstone and siltstone beds throughout; mostly covered	15 +/-
3.	Sandstone, buff to gray, fine gr.; very massive with large trough cross stratification and horizontal laminae; some troughs are 8 ft. across and 3 ft. deep; well sorted	17 +/-

APPENDIX 1 (Contd.)

		Thickness in Feet
2.	Silty shale, buff; abundant ferrugenous nodules and silt laminae	5.0
1.	Sandstone, buff, fine gr.; thin to medium bedded; trough cross stratification and horizontal laminae .	9 +/-
	Total	74 ft.

Section 8

Measured northward up pipeline 3 miles west-northwest of Bridgeport, Texas; pipeline crosses Hwy. 1658 running north-south and continues up and over Chico Ridge escarpment.

4.	Limestone, gray to buff, crinoid-phylloid algal biomicrudite and biosparite; bedding irregular and uneven, beds up to 1.5 ft. thick; Devil's Den Limestone	22.0
3.	Silty shale, gray to buff, marly; limy lenses and thin limestone beds; tubular sponges common, crinoids; limestone beds up to 2 in. thick	33.0
2.	Sandstone beds in shale, gray to buff to reddish; fine gr. sandstone beds up to 3 ft. thick in silty, sandy shale; sandstone beds appear locally squeezed and scoured; mostly covered	44.0
1.	Sandy, silty shale, gray to buff; fine gr. sandstone beds up to 1.5 ft. thick common; sandstone beds increase in number upward, sandstones show mostly horizontal laminae; shale appears laminated to homogenous; no fossils noted	60.0
	Total	159.0 ft.

Section 9

Measured from intersection with county road up road to Sid Richardson Scout Ranch; 3.7 miles east of Wizard Wells, Texas.

APPENDIX 1 (Contd.

	Thickness in Feet
9. Limestone, gray to buff to white, phylloid algal biosparudite and biomicrudite; beds uneven and irregular approximately 1 ft. thick; thin calcareous shale zones separate limestone beds; solitary corals present but not abundant	21.0
8. Marly, calcareous shale, buff to gray; thin, uneven, sandy biosparite and biomicrite beds and lenses in marly shale; phylloid algal blades, crinoids, fusulinids common throughout	19.0
7. Sandy, silty shale, buff to gray; lower 6 ft. contain very fine gr. sandstone and siltstone beds up to 2 in. thick; upper several feet contain streaks of calcareous sandstone and sandy limestone, some thin calcareous beds show ripples on upper surfaces; mostly a homogenous to well laminated silty, sandy shale	55.0
6. Sandstone, buff to reddish, fine gr.; massive in appearance, medium trough cross stratification, local planar-tabular cross stratification, local horizontal laminae; pockets of ferrugenous nodules, plant debris; entire sandstone body appears somewhat lens-shaped	44.0
5. Silty, sandy shale, buff; unfossiliferous; mostly covered	2.0
4. Sandstone, buff, fine to very fine gr.; massive; abundant, macerated, black plant material throughout; no sedimentary structures notes	4.0
3. Silty, sandy shale, buff; badly covered	5.0
2. Sandstone, buff to gray, very fine gr.; thin beds up to 10 in., individual beds show current ripple laminae, small flute casts, drag marks, various tracks and trails on bedding surfaces	13.0
1. Silty, sandy shale, brown to reddish; contains local thin, fine sandstone beds up to 4 in. thick; mostly covered	17.5
Total	180.5 ft.

APPENDIX 1 (Contd.)

Section 10

Measured from head of small tributary creek northward up Devil's Den escarpment; 1.2 miles due east of Vineyard, Texas.

		Thickness in Feet
5.	Limestone, buff to gray to white, phylloid algal biomicrudite and biosparudite; irregular, uneven beds; Devil's Denn Limestone	16.0
4.	Marly shale, buff; silty; thin, calcareous beds and lenses; abundant crinoids	12.0
3.	Sandy, silty shale, buff to gray; fine- to very fine-gr. sandstone beds up to 1 foot thick locally distributed; sandstone beds show local ripples, trough cross stratification, horizontal laminae abundant; local tracks and trails on bedding surfaces; shale is silty and well laminated to homogenous	44.0
2.	Sandstone, buff to gray, fine gr.; heavily burrowed, vertical and horizontal burrows up to 1 in. in diameter; local in-place articulated Myalina shells . .	2.0
1.	Silty shale, buff to gray; abundant, thin siltstone laminae; local thin sandstone beds; abundant reddish ferrugenous nodules; unfossiliferous	99.0
	Total	173.0 ft.

Section 11

Measured from base of Devil's Den outlier directly behind Yates sale barn on Yates Ranch; one mile southeast of Vineyard, Texas.

5.	Limestone, gray, phylloid algal-crinoid-bryozoa biosparite and biomicrite; irregular and uneven bedding, well indurated; Devil's Den Limestone	20.0
4.	Marly, silty shale, buff to gray; thin limestone beds and lenses; mostly covered	60.0
3.	Sandstone, buff, fine to very fine gr.; burrowed, contains Myalina shells	2.0

APPENDIX 1 (Contd.)

		Thickness in Feet
2.	Covered; probably thin fine-gr. sandstone beds in silty shale	26.0
1.	Silty shale, buff; local thin fine- to very fine-gr. sandstone beds up to 2 in. thick; laminated; mostly covered	53.0
	Total	161.0 ft.

Section 12

Measured up northern end of southeasternmost Devil's Den Limestone outlier on Yates Ranch; 1.2 miles south of Vineyard, Texas.

9.	Limestone, gray to buff, phylloid algal-crinoid biosparudite and biomicrudite; irregular and uneven beds, well indurated; Devil's Den Limestone	25.0
8.	Silty shale and thin sandstone beds, gray; mostly covered; sandstone beds up to 1 ft. thick and heavily burrowed, burrows branching and up to 0.5 in. in diameter; silty shale is laminated to bioturbated . .	26.0
7.	Sandstone, buff, fine gr.; heavily burrowed, vertical and horizontal branching burrows up to 1 in. in diameter; articulated _Myalina_ shells	3.0
6.	Silty shale, buff to gray; local thin marly and limy lenses, crinoid debris common; bioturbated	7.0
5.	Siltstone and laminated sandstone, buff, very fine gr.; thin fissile laminae, ripple laminae throughout; appears locally burrowed	11.0
4.	Sandstone, buff, very fine gr.; ripples throughout, possible cancellation ripples; poorly indurated fissile laminae	1.5
3.	Silty, sandy shale, buff; thin, very fine-gr. local sandstone beds, abundant crinoid debris and ferrugenous nodules; local small sandstone flow rolls . .	36.0

APPENDIX 1 (Contd.)

		Thickness in Feet
2.	Sandstone, buff to gray; flow roll zone, fine to very fine-gr.; individual sandstone rolls up to 1.5 ft. across, strongly contorted; upper 1 ft. rippled sandstone beds 2 to 3 in. thick, may be oscillation ripples	4.0
1.	Silty shale, buff; percentage of silt laminae increases upward; local reddish ferrugenous nodules; unfossiliferous; shale appears laminated . .	17.5
	Total	131.0 ft.

Section 13 (See Fig. 15)

Measured from creek level at southernmost end of southern Devil's Den outlier on Yates Ranch; 2 miles south-southwest of Vineyard, Texas.

9.	Silty, sandy shale, buff to reddish; upper 1 ft. thin, fine-gr. sandstone beds with mostly horizontal laminae; unit appears bioturbated	6.0
8.	Limestone, gray, phylloid algal biomicrudite and biosparudite; nodular in appearance; irregular beds up to 8 in. thick; brachiopods, crinoids; Devil's Den Limestone	2.5
7.	Shale, buff, silty, sandy, calcareous; exceedingly fossiliferous, crinoids, sponges, bryozoa, orthocone nautiloids, mollusks; zone becomes increasingly calcareous toward top	20.0
6.	Sandstone, gray, fine to very fine gr.; trough cross stratification up to 3 ft. across; ripple laminae; upper 1 ft. is vuggy and heavily burrowed, burrows both vertical and horizontal up to 1 in. in diameter	3.5
5.	Silty shale, buff to gray; local marly to calcareous lenses; abundant crinoid debris, bryozoa, sponges; appears heavily bioturbated	16.0
4.	Sandstone, gray, fine to very fine gr.; vuggy, heavily burrowed, burrows have no preferred orientation . . .	4.5
3.	Silty shale, buff to gray; abundant reddish ferrugenous nodules and crinoid debris; tubular branching bryozoa; appears bioturbated	16.0

APPENDIX 1 (Contd.)

		Thickness in Feet
2.	Sandstone, gray to buff, fine to very fine gr.; trough cross stratification up to 4 or 5 ft. across; base has load casts and large horizontal burrows; upper surface has excellent straight crested oscillation ripples	2.5
1.	Silty, sandy shale, buff to gray, thin fine gr.; sandstone beds up to 10 in. thick are heavily burrowed, branching burrows up to 1 in. in diameter, burrows mostly horizontal; sandstone beds show ripple laminae; silty shale is laminated and contains abundant reddish ferrugenous nodules	47.0
	Total	118.0 ft.

Section 14 (See Fig. 15)

Measured from creek level, 0.3 mile west of southern tip of southernmost Devil's Den outlier, on Yates Ranch; 2.2 miles south-southwest of Vineyard, Texas; 0.2 mile east of Hwy. 1156.

2.	Sandstone, buff to reddish, fine gr.; massive squeezed and contorted sandstone boulders weathering out, large scale trough cross stratification and horizontal laminae in upper 6 to 8 ft.; base scoured into underlying sandy shale; sandstone well sorted with abundant plant material; sandstone thins and pinches out eastward; thinner uppermost beds are strongly rippled . . .	25.0
1.	Sandy, silty shale, buff to reddish; fine-gr. sandstone beds up to 1 ft. thick prominent near top of interval; silty shale is laminated to homogenous, unfossiliferous; ferrugenous nodules	42.0
	Total	67.0 ft.

Section 15

Measured from road level along Hwy. 1156, 2.3 miles south-southwest of Vineyard, Texas; on Roper Ranch, west of highway.

APPENDIX 1 (Contd.)

		Thickness in Feet
4.	Sandstone, buff, fine gr.; beds up to 4 ft. thick, trough cross stratification up to 3 ft. across; locally appears squeezed and contorted; well sorted; base covered	6.0
3.	Covered; probably thin fine-gr. sandstone beds in silty shale	15.0
2.	Sandy, silty shale, buff to gray; thin, fine-gr. sandstone beds up to 10 in. thick increase in number upward; shale contains local crinoid columnals and sponges; mostly covered	66.0
1.	Sandstone, buff, fine to medium gr.; massively bedded, beds up to 6.5 ft. thick, large trough cross stratification; weathered boulders are locally squeezed and contorted; abundant plant material including whole leaves and plant stems; sandstone is well sorted and contains local clay chips; lower few ft. is thinner bedded with individual beds up to 2 ft. thick; upper several ft. contain pockets of ferrugenous nodules, some of which are up to 3 in. in diameter	75 +/-
	Total	162.0 ft.

Section 16

Measured up hillside west of Hwy. 1156, 2.8 miles south of Vineyard, Texas; on Roper Ranch, 0.3 mile east-southeast of old Roper house, on west side of highway.

2.	Sandy, silty shale, buff to gray; numerous fine- to very fine-gr. sandstone beds up to 10 in. thick in silty shale; sandstones show horizontal tracks and trails and horizontal laminae; local ripples; silty shale is laminated to homogenous; plant debris common	12.0
1.	Silty shale, gray to buff; local fine- to very fine-gr. sandstone beds up to 1 ft. thick, which show small flute casts, horizontal tracks and trails, fern leaf impressions and other plant debris; shale has abundant large crinoid columnals and other debris; gastropods, Productid-type brachiopods; one small, spiral phosphatic coprolite found	60.0
	Total	72.0 ft.

APPENDIX 1 (Contd.)

Section 17

Measured up hillside from level of pond, on Roper Ranch, 0.6 mile west of Hwy. 1156; approximately 2.4 miles north-northwest of Joplin, Texas.

		Thickness in Feet
5.	Covered; probably thin, fine-gr. sandstone beds in silty shale	5.0
4.	Sandstone, buff, fine gr.; massive in appearance, squeezed and contorted, local trough cross stratification, local horizontal laminae	10.0
3.	Covered; probably thin, fine-gr. sandstone beds in silty shale	11.0
2.	Sandstone, buff, fine to very fine gr.; beds up to 1.5 ft. thick; clean, well sorted, some plant debris	5.5
1.	Silty, sandy shale, gray to buff; abundant reddish ferrugenous nodules, local crinoid columnals; local thin, fine-gr. sandstone beds have horizontal tracks and trails, flute casts; sandstone beds up to 10 in. thick	58.0
	Total	89.5 ft.

Section 18

Measured up hillside on Roper Ranch 0.7 mile west of Hwy. 1156 and 1.6 miles north of Hwy. 199; just west of Beans Creek in eastern Jack County; 2.1 miles north-northwest of Joplin, Texas.

3.	Covered; probably thin, fine-gr. sandstone beds in silty shale	7.0
2.	Sandstone, buff, fine gr. to very fine gr.; beds up to 3 ft. thick; contorted to scoured, plant debris throughout	6.0
1.	Sandy, silty shale, gray; shale well laminated, abundant reddish ferrugenous nodules up to 3 in. in diameter; thin, fine-gr. sandstone beds have	

APPENDIX 1 (Contd.)

	Thickness in Feet
small flute and groove casts, load casts common; sandstone beds up to 4 in. thick more abundant near top of unit	82.0
Total	95.0 ft.

Section 19

Measured westward up dirt road from old house and barn up to house at top of hillslope; 0.4 mile north of Hwy. 199 in eastern Jack County; 1.2 miles northwest of Joplin, Texas.

7. Silty, sandy shale, reddish brown; contains some thin, very fine-gr. sandstone beds and local small flow rolls and contorted sandstone beds; shale laminated, with abundant silt laminae	5.5
6. Sandstone, buff, fine gr.; horizontal laminae, single flag-like bed	0.5
5. Silty shale, buff; laminated, unfossiliferous	2.5
4. Silty sandstone, buff, very fine gr.; sandstone and silt, thin flaggy beds up to 4 in. thick; horizontal laminae, load casts, local small trough cross stratification	2.5
3. Silty shale, reddish to buff; laminated, unfossiliferous	2.0
2. Sandstone and siltstone, buff to reddish; very fine-gr., flaggy beds up to 10 in. thick; horizontal laminae, local load casts	3.5
1. Sandy, silty shale, buff to reddish to purple; local fine- to very fine-gr. sandstone beds up to 3 in. thick; sandstones show horizontal laminae and an assortment of load casts; shale is silty and well laminated	41.0
Total	55.5 ft.

APPENDIX 1 (Contd.)

Section 20

Measured up county dirt road north of Hwy. 199 in two parts (See Plate I); begins at level of Beans Creek and continues westward up road around first curve; second part of section begins at sharp right-hand curve in road and proceeds northwestward to top of hill.

		Thickness in Feet
10.	Sandstone, buff to reddish, fine to medium gr.; local ferrugenous nodules and abundant fine clay chips, trough cross stratification abundant throughout; locally contorted; local burrows up to 1 in. in diameter	11.0
9.	Shale, buff to maroon; silty, abundant reddish ferrugenous nodules; unfossiliferous	13.0
8.	Covered; massive contorted fine- to medium gr. sandstone blocks lying around on surface, these contain local reddish ferrugenous nodules	6.0
7.	Silty, sandy shale, buff to reddish; laminated, local fine- to very fine-gr. sandstone beds up to 2 in. thick	21.0
6.	Sandstone, buff, fine gr.; beds 1.5 ft. thick, trough cross stratification up to 3 ft. across, horizontal laminae; clean, well sorted; woody plant debris common; possibly channel-like	5.0
5.	Shale, dark gray; well laminated, local reddish to maroon streaks; unfossiliferous	11.0
4.	Silty sandstone and shale, buff to gray; alternating thin fine-gr. to very fine-gr. sandstone beds, silt layers, and silty shale; sandstone beds up to 4 in. thick, mostly horizontal laminae with local ripples; shales are gray to purple, laminated, unfossiliferous .	20.0
3.	Silty, sandy shale, gray to buff; local thin, very fine-gr. sandstone beds; shale well laminated, reddish ferrugenous nodules	30.0

APPENDIX 1 (Contd.)

		Thickness in Feet
2.	Sandy, silty shale, buff; numerous thin, flaggy, very fine-gr. sandstone and siltstone beds up to 4 in. thick; load casts and horizontal trails and tracks common; horizontal laminae predominant in sandy units; shales are silty and well laminated . . .	22.0
1.	Shale, gray to buff; somewhat silty, laminated, unfossiliferous	11.0
	Total	150.0 ft.

Section 21

Measured up county dirt road east of Hwy. 281 and southwest of Hwy. 199 in southeastern Jack County (See Plate I); measured from Beans Creek tributary, northwestward up road to level of house on top of hill.

9.	Sandstone, buff to reddish, fine gr.; massive in appearance, probably trough cross stratification; mostly covered	4.5
8.	Covered; probably silty, sandy shale	2.0
7.	Sandstone, buff, fine gr.; trough cross stratification, massive in appearance; appears to be scoured down into underlying sandstone; probably channel-like; poorly exposed	5.5
6.	Sandstone, light gray to white, fine to very fine gr.; clean, well sorted, mostly horizontal laminae, local small troughs, horizontal burrows; beds up to 1 ft. thick	5.0
5.	Shale, purple to gray to buff; silty, unfossiliferous; abundant silty boxwork structures weathering out may be due to brine intrusion	3.0
4.	Sandstone, gray to white, very fine gr.; beds up to 1 ft. thick, very clean, well sorted, mostly horizontal laminae, local trough cross stratification up to 1 ft. across; excellent ripples preserved on top of unit may be oscillation type	3.0

APPENDIX 1 (Contd.)

		Thickness in Feet
3.	Silty, sandy shale, gray to buff to purple; sparse, very fine-gr. sandstone beds up to 4 in. thick; sandstones show mostly horizontal laminae with local trails and tracks, local load casts, sandstone beds more abundant toward top of interval; shale is silty and well laminated; unfossiliferous	82.0
2.	Sandstone, buff, fine gr.; well sorted; beds up to 1 ft. thick, lower bed contains local clay chips up to 2 in. across and appears trough cross stratified; upper 1 ft. thin bedded sandstone	2.0
1.	Silty, sandy shale, purple to gray to buff; laminated, unfossiliferous	6.0
	Total	113.0 ft.

Section 22

Measured northward from base of hill, 0.4 mile east of East Fork of Keechi Creek in southeast Jack County; 3.3 miles northwest of Perrin, Texas.

3.	Sandy, silty shale, buff to reddish; upper 5 ft. has fine-gr. sandstone beds up to 10 in. thick; reddish ferrugenous nodules common, unfossiliferous; mostly covered	23.0
2.	Sandstone, buff, fine gr.; massive in appearance; slightly contorted, local troughs, local ferrugenous nodules	3.0
1.	Sandy, silty shale, buff; thin fine-gr. sandstone beds increase in number in upper 20 ft.; sandstone beds up to 1 ft. thick, plant debris, load casts, small flow rolls, trails and tracks locally; shale contains ferrugenous nodules and is fissile; silty laminae throughout; a few scattered crinoid columnals; 0.1 mile to the west unit contains a 7 ft. thick channel-like fine-gr. sandstone in upper 20 ft., which contains trough cross stratification, contorted bedding, local concentrations of ferrugenous nodules	52.0
	Total	78.0 ft.

APPENDIX 1 (Contd.)

Thickness in Feet

Section 23

Measured northward up hill just north of Hwy. 2210; 2.8 miles due west of Perrin, Texas, and just east of the East Fork of Keechi Creek.

2.	Sandstone, buff, fine gr.; very massive, somewhat contorted; horizontal laminae, trough cross stratification, weathered boulders the size of small houses, dip averages 25° toward the south; entire sandstone body appears slumped or faulted; plant debris; possibly a scoured base	45 +/-
1.	Silty shale, gray to buff; reddish ferrugenous nodules, abundant ferrugenous siltstone laminae; local, very fine-gr. sandstone and siltstone beds up to 8 in. thick with horizontal and ripple laminae; shale well laminated, locally contorted, thin sandstone beds become more numerous upward, local small sandstone flow rolls; east end of exposure shows an 8 ft. thickness of thick-bedded, fine-gr. sandstone which has slumped down into the shale from above--appears to be penecontemporaneous, soft-sediment slump	63.0
	Total	108.0 ft.

Section 24

Measured along Hwy. 2210 up Winchell escarpment; halfway between Perrin and Barton's Chapel, Texas; measured from north to west curve in road to top of hill; 6.3 miles due east of Barton's Chapel.

7.	Limestone, gray to white, phylloid algal-crinoid biomicrudite and biosparudite; fenestrate bryozoa and brachiopods; thin zones of terrigenous mud separating irregular thin limestone beds; Winchell Limestone	25.0
6.	Shale, gray to buff; lower 20 ft. very rich in ferrugenous nodules; crinoids, small brachiopods, fusulinids; upper 31 ft. more calcareous with abundant crinoids; unit becomes calcareous toward	

APPENDIX 1 (Contd.)

		Thickness in Feet
	top; 31 ft. below base of Winchell Limestone is a 1 ft. thick, fine gr. sandstone unit containing local contorted flow rolls	51.0
5.	Sandstone, buff, fine gr.; massive, trough cross stratification up to 6 ft. across, upper 1.5 ft. is thin-bedded, burrowed sandstone	18.5
4.	Silty calcareous shale, buff to gray; crinoids, solitary corals, fusulinids; abundant reddish ferruginous nodules; laminated to bioturbated	10.0
3.	Limestone, buff; poorly indurated, muddy crinoid-brachiopod-coral-fusulinid biomicrudite; possible phylloid algal blades	1.5
2.	Sandstone, buff, fine to very fine gr.; beds up to 0.5 ft. thick; each bed has oscillation and/or cancellation ripples on upper surface; local tracks and trails	5.0
1.	Silty shale, gray to buff; local thin silt laminae; unfossiliferous	21.0
	Total	132.0 ft.

Section 25

Measured along county road from level of house on west side of road, up and around the north to east curve to Sparks Spring Church; 4.7 miles northwest of Perrin and 6.1 miles east of Barton's Chapel.

3.	Silty, sandy shale, buff to reddish; abundant thin silt laminae; local thin, very fine-gr. sandstone beds; unfossiliferous	18.0
2.	Sandstone, buff to reddish, fine gr.; massive; local ferrugenous nodules, locally trough cross stratified; poorly exposed	25.0
1.	Silty, sandy shale, gray to buff; abundant silt laminae and reddish ferrugenous nodules in lower several feet; thin fine- to very fine-gr. sandstone	

APPENDIX 1 (Contd.)

		Thickness in Feet
	beds up to 1 ft. thick increase in abundance in upper part of unit	46.0
	Total	89.0 ft.

Section 26

Measured northward up county road at location indicated on Plate I; from just south of slight eastward bend in road up to flat break in slope.

3.	Sandstone and silty shale, buff; fine- to very fine-gr. sandstone beds up to 10 in. thick in silty shale; mostly covered	10.0
2.	Sandstone, light gray, fine gr.; firmly cemented with calcite cement; almost a sandy limestone; no fossils noted	1.5
1.	Sandy siltstone, buff; closely packed, thin very fine-gr. sandstone and siltstone beds; thin siltstone beds up to 1 in. thick show tracks and trails; lower 8 ft. silty shale	30.0
	Total	41.5 ft.

Section 27

Measured northward up county road at location indicated on Plate I; from 8 ft. above level of pipeline crossing to VAMB Richards tower (to top of Ranger Limestone scarp).

8.	Limestone, light gray, crinoid-phylloid algal biomicrudite and biosparudite; firmly indurated, irregular beds up to 1 ft. thick; Ranger Limestone	4 +/-
7.	Sandy silty shale, reddish to gray; one poorly indurated fine gr. sandstone unit 2 ft. thick in lower 5 ft.; thin sandy zones near top	12 +/-
6.	Limestone, gray, rippled intraclastic biosparudite; appears to have been deposited as a muddy carbonate sand; abundant crinoids, Productid brachiopods; beds up to 1 ft. thick; Ranger Limestone	3.0

APPENDIX 1 (Contd.)

	Thickness in Feet
5. Silty shale, gray to purple; thin siltstone beds up to 2 in. thick; largely unfossiliferous, one Spirifer-type brachiopod found	18.0
4. Sandstone, buff, fine to very fine gr.; sandstone in beds up to 1 ft. thick; no sedimentary structures visible	4.0
3. Sandstone, buff, fine gr.; massive; trough cross stratification; locally contorted; contains plant debris and pea-sized clay chips locally; mostly well sorted	17.0
2. Sandy siltstone, and silty shale, buff; abundant reddish ferrugenous nodules; local beds and lenses up to 10 in. thick of very firmly indurated sandy, sparry limestone; upper 15 ft. silty shale; local black shale	45.0
1. Silty sandstone, buff, fine to very fine sandstone and siltstone in thin beds, abundant plant debris, poorly indurated, soft	3.5
Total	106.5 ft.

NOTE: Sections 26 and 27 can be combined with a 12 ft. covered interval between. Section 27 is on top.

Section 28

Measured along county road at position indicated on Plate I; 2.5 miles northeast of Oran, Texas, in Oran Sandstone interval; from pond just south of county road eastward to top of hill.

2. Sandstone, buff to reddish, fine gr.; irregular highly trough cross stratified beds up to 1 ft. thick; base abrupt and scoured into underlying shale; entire unit composed of trough cross stratification up to 5 ft. across and 1 ft. deep; abundant plant debris, local clay pebbles up to 1 in. in diameter .	25.0
1. Silty, sandy shale, gray to buff; numerous fine silt laminae; unfossiliferous; upper 3.5 ft.	

APPENDIX 1 (Contd.)

		Thickness in Feet
	contains numerous thin siltstone beds up to 0.5 in. thick; reddish ferrugenous nodules within silty zone	37.0
	Total	62.0 ft.

Section 29

Measured eastward up southwest facing slope of hill directly north of Barton's Chapel cemetery, near Barton's Chapel, Texas; on Charles Geer's land.

6.	Conglomerate, reddish to gray; chert pebbles and other rock fragments up to 1.7 in. in diameter; coarse-gr. sandstone intermixed; large trough cross stratification throughout; pebble size averages 0.5 in.; material is well sorted	26 +/-
5.	Covered; probably fine-gr. sandstone beds in silty shale	16.0
4.	Sandstone, buff, fine gr.; squeezed and contorted; massive; local trough cross stratification; plant debris	31.0
3.	Covered; probably sandy, silty shale; sandstone beds seem to increase in number upward	24.0
2.	Limestone, dove, phylloid algal biosparudite and biomicrudite; uneven beds up to 2 ft. thick; crinoids, bryozoa, *Spirifer*-type brachiopods; Ranger Limestone	5.5
1.	Silty calcareous shale, gray to buff; thin limestone beds and lenses increase upward; mostly covered	24.0
	Total	126.5 ft.

Section 30

Measured northward up dirt county road to top of steep hillslope, from level of small tributary creek just up from cow pond; 3.3 miles west of Barton's Chapel, Texas.

APPENDIX 1 (Contd.)

	Description	Thickness in Feet
15.	Conglomerate, buff to reddish; chert pebbles and fine- to coarse-gr. sandstone intermixed, strongly scoured channels; pebbles range from pea size up to 1.5 in. across	42 +/-
14.	Covered; local conglomeratic beds up to 4 ft. thick; silty and sandy near top	22 +/-
13.	Silty shale, buff to reddish; laminated; no fossils noted	6.0
12.	Sandstone, buff to reddish, fine gr.; beds up to 4 ft. thick, beds thicken upward, local small to medium scale trough cross stratification; somewhat contorted locally	13 +/-
11.	Covered; approximately 5 ft. of chert pebble conglomerate in lower part of unit	14 +/-
10.	Silty, sandy shale, buff; local crinoids and Productid-type brachiopods; thin fine-gr. sandstone beds increase in number upward; rippled sandstone beds up to 1 ft. thick in upper 10 ft.; reddish ferrugenous nodules abundant in basal shales	41 +/-
9.	Conglomerate, buff to reddish; chert pebbles and medium- to coarse-gr. sandstone throughout; trough cross stratification throughout, scoured base	9 +/-
8.	Sandstone and shale, buff to reddish; upper 6 ft. fine- to medium-gr. sandstone beds in shale; sandstone beds show trough cross stratification; shales silty and laminated	22.0
7.	Covered; probably thin, fine-gr. sandstone beds in silty shale; one sandstone bed may be 2 ft. thick; upper 8 ft. appears to be a chert pebble conglomerate intermixed with coarse sandstone	23.0
6.	Limestone, buff, biomicrudite; abundant shelly debris, bioturbated; brachiopods, mollusks, crinoids	1.0
5.	Silty, sandy, marly shale; buff, heavily bioturbated; very rich in crinoid columnals, several varieties of brachiopods, fenestrate and encrusting bryozoa, <u>Girtyocoelia</u> sponges, mollusks; unit becomes somewhat more sandy toward the top	8.5

APPENDIX 1 (Contd.)

	Thickness in Feet
4. Limestone, buff, sandy and gravelly; jumbled crinoid columnals, brachiopods, plant debris up to several inches in length; a well indurated gravel or conglomerate made of shelly hash and chert pebbles; basal Home Creek Limestone	1.0
3. Sandstone and silty shale, buff to gray; very fine-gr. sandstone and siltstone in beds up to 4 in. thick; rippled, local plant debris; grades upward into overlying unit	3.0
2. Coal, black; very fissile, muddy, and poorly indurated, compressed plant hash	2.0
1. Silty, sandy shale, gray to buff to dark gray above; no fossils noted	19.0
Total	226.5 ft.

Section 31

Measured up hill directly across county road from Halsell Ranch house in southwestern Jack County; 3.4 miles southwest of Barton's Chapel.

10. Limestone, gray, phylloid algal biomicrite; upper beds are brecciated or intramicrudite; Ranger Limestone	2.0
9. Sandstone beds in shale, buff; fine-gr. sandstone beds up to 6 in. thick in silty shale; mostly covered	8.0
8. Limestone, gray, phylloid algal biomicrudite; uneven beds up to 1 ft. thick; local crinoids, abundant fusulinids in upper 1 ft.; Ranger Limestone	6.0
7. Shale, buff, marly; local thin calcareous zones; badly covered	22.0
6. Sandstone, buff, fine gr.; somewhat contorted, massively bedded, local trough cross stratification up to 3 ft. across; plant debris; a local channel unit, grades laterally to the east into shale and limestone	15.0

APPENDIX 1 (Contd.)

	Thickness in Feet
5. Limestone, buff to brown, biosparudite; abundant crinoid columnals, Productid-type brachiopods, <u>Myalina</u>, <u>Spirifer</u>-type brachiopods, bryozoa, fusulinids; a well winnowed calcareous sand and gravel	1.0
4. Calcareous shale, buff; richly fossiliferous; crinoids, Productid-type brachiopods, gastropods; large reddish ferrugenous nodules abundant in lower 18 ft.; more fossiliferous toward top	27.0
3. Sandy limestone and calcareous sandstone, light gray; well indurated	1.0
2. Sandstone, buff, fine gr. to very fine gr.; holds up prominent escarpment; entire interval consists of ripple laminae with small to medium scale trough cross stratification in upper 3 ft.; base gradational with underlying shale; one thick sandstone unit; upper sandstone appears to become more massive and homogenous to the west where it crosses the county road	14.0
1. Silty, sandy shale, buff to reddish brown; numerous thin silty and sandy beds increase in number upward, good progradational sequence; well laminated throughout; grades upward into overlying sandstone; abundant reddish ferrugenous nodules; no fossils noted	44.0
Total	140.0 ft.

MEASURED SECTION OUTSIDE MAPPED AREA

Measured just west of Stephens-Palo Pinto County line in Stephens County; along Hwy. 207 approximately 8 miles northwest of Strawn, Texas; measured through Winchell Limestone on top of hill from sandstone cut at road level (see Fig. 11).

10. Limestone, light gray to white, phylloid algal biomicrudite; uneven irregular beds; locally rich in fusulinids and crinoid debris; top 1 ft. is a silicified coquina of whole pelecypod shells and shell hash (a biosparudite) appears to be a shoal deposit; Winchell Limestone	33.0

APPENDIX 1 (Contd.)

		Thickness in Feet
9.	Calcareous shale; badly covered; becomes increasingly calcareous upward	22.0
8.	Limestone, gray, phylloid algal-brachiopod-gastropod biomicrudite and biosparudite; locally packed with phylloid algal blades; Winchell Limestone	2.5
7.	Calcareous silty shale, gray; mostly covered; becomes progressively more calcareous upward; no fossils noted	13.0
6.	Sandstone, buff, fine to medium gr.; massive, small to medium scale trough cross stratification throughout; poorly exposed	25.0
5.	Sandy, silty shale, buff to gray; badly covered; probably thin, fine- to very fine-gr. sandstone beds in silty shale	16.0
4.	Sandstone, buff, fine to medium gr.; massive, large trough cross stratification throughout; abundant woody plant debris up to several inches long, <u>Calamites</u>; abundant fine clay chips	26.0
3.	Sandy, silty shale, gray; mostly covered; thin, fine- to very fine-gr. sandstone beds in silty shale.	15.5
2.	Sandstone, buff, fine to very fine gr.; a series of sandstone lenses and scours; beds thinner below becoming more massively bedded above; small to medium scale trough cross stratification; fine plant debris common throughout; approximately 3 ft. from base is a 2 ft. zone of heavily squeezed and contorted sandstone beds; base is locally slumped to squeezed and contorted to scoured down into underlying sandy shale; local flow rolls near base, especially at west end of roadcut, appears extensively loaded; local clay chip concentrations in the sandstone; entire unit grades laterally into sandy silty shale, sandstone body approximately 150 yards across; unit well exposed in long roadcut at county line	12.0
1.	Sandstone and silty, sandy shale, gray to buff; thin fine- to very fine-gr. sandstone beds in silty, sandy shale; locally deformed and rolled near top, local sandstone flow rolls	4.0
	Total	169.0 ft.

APPENDIX 2

LOCALITIES AND EXPOSURES OF INTEREST

(See Geologic Map, Plate I, for Locations)

NOTE: Each of the measured sections described in Appendix 1 contains fair to excellent exposures of deltaic, fluvial, and shallow shelf facies. The short list of Localities given here is intended only as a supplement to the more extensive listing of Appendix 1.

A. Massive distributary channel-fill sandstone unit in upper part of Colony Creek Formation--This is a good exposure (roadcut at junction of Highway 59 and F.M. Road 1810) of an 8 ft. thick distributary channel, which scoured through underlying inter-distributary mudstone. The sharp, erosional character of the basal contact, and the massive and well sorted nature of the sandstone is well characterized.

B. Strike-fed, delta-destructional sandstone unit in upper part of Colony Creek Formation--Here, a relatively good exposure (4 ft. thick) of highly burrowed, reworked, delta-destructional sandstone caps a shale bluff on the M. L. Steward Ranch (0.2 mile west of road). The sandstone is riddled with vertical and sub-vertical burrows up to 0.75 inch in diameter and several inches long, and contains impressions of mollusk fragments and brachiopod valves.

C. Massive, squeezed and contorted, delta-front and distributary channel-fill sandstone in middle to upper parts of the Placid Formation--Here, the contorted and rolled nature of massive Perrin delta sandstone units can be seen in weathered boulders just west of the county road.

D. Distributary channel-fill and delta-front sandstone facies, and shallow-shelf carbonate tongues of the Chico Ridge carbonate bank--Here, a one mile long spillway for Lake Bridgeport exposes Perrin delta sandstone and mudstone units of the Jasper Creek Shale (Upper Wolf Mountain Formation) overlain by carbonates tongues. The Chico Ridge carbonate bank is well developed (150 ft. thick) 1 mile to the north-northeast of this spillway.

E. Wildly slumped and contorted delta-front sandstone beds (see Fig. 12) in the lower part of the Lake Bridgeport Shale (Lower Wolf Mountain Formation)--Here, delta-front sand units slumped into unstable, water-saturated prodelta muds of the Perrin delta, giving spectacular contorted and rolled structures. These features are exposed in a roadcut along Highway 380 on the northwest side of Bridgeport, Texas.

APPENDIX 2 (Contd.)

F. Limestone breccia and intramicrudite (Rock Hill Limestone) in the middle part of the Wolf Mountain Formation--The Rock Hill Limestone was shed as a partially to completely prelithified carbonate talus lateral to the early developing Chico Ridge bank, to the northeast. The 2 ft. thick limestone is well exposed above fossiliferous shelf mudstone in a roadcut along Highway 380.

G. Massively bedded delta-front sandstone beds in lower Jasper Creek Shale (Wolf Mountain Formation)--Here, bedded delta-front sandstone beds of a minor Perrin delta lobe overlie sandy, silty prodelta facies and are fairly well exposed along a railroad cut of the Chicago, Rock Island, and Pacific Railroad.

H. Distributary channel-bar crest sandstone facies in upper part of Wolf Mountain Formation (see Fig. 15)--Here, trough cross stratified and horizontally laminated to rippled distributary and bar crest facies of a Perrin delta lobe are exposed in a roadcut along F. M. Road 1156.

I. Unevenly bedded, shallow shelf, algal carbonate facies (Upper Member, Ranger Limestone)--Here, an excellent 15 ft. thick exposure of the shallow, transgressive shelf Ranger Limestone overlies rolled and contorted distal prodelta facies of a minor delta lobe.

J. Distributary channel-fill facies (see Fig. 14) in lower part of Colony Creek Formation--Here, massive to trough cross stratified distributary channel sandstone is exposed in roadcuts along Highway 380. Excellent examples of contemporaneous soft-sediment faulting can be seen here, as well as a mudstone- and coal-filled abandoned channel cutout.

K. Distributary channel-fill facies in middle to upper part of Colony Creek Formation--Here, a trough cross stratified and somewhat slumped, minor distributary channel sandstone unit is fairly well exposed in a roadcut west of the Halsell Ranch in southern Jack County.

L. Shallow marine, transgressive shelf carbonate facies (Ranger Limestone) --Here, the shallow shelf Ranger Limestone is well developed (40-50 ft. thick) and is exposed in a roadcut along State Highway 16 in northwestern Palo Pinto County.

APPENDIX 3

CORE DESCRIPTIONS, NORTHWESTERN WISE COUNTY

See Plate V for Locations

MOBIL CORE HOLE NO. 10
(Designated Core Hole #2, This Report)

Depth in Feet	
882.5 - 906.5	Mudstone, dark gray to black with red ferrugenous lenses and nodules; thin silt laminae common, platy to flaky, unevenly laminated, locally appears bioturbated, fine flecks of black plant debris common.
906.5 - 920.5	Sandstone, buff, fine grained; black plant debris throughout often concentrated in wisps and lenses, siderite cemented zones throughout, often weathering to red; sandstone appears homogenous, no structures noted, local reddish ferrugenous nodules, local lenses of black plant debris in thin laminae become common from 914 through top of unit; unit is very fine sandstone from approximately 910.5 through top.
920.5 - 921	Sandy siltstone, dark gray to black; contains reddish ferrugenous nodules, unevenly laminated throughout, fine black organic flecks throughout; a muddy organic rich siltstone near top, grades upward into fine sandstone.
921 - 922	Silty sandstone, gray, very fine grained; appears ripple bedded near base; wisps of black plant debris line local laminae planes; fine organic flecks throughout.
922 - 942	Mudstone, silty, with local red ferrugenous lenses and nodules; platy to fissile, locally well laminated, black plant debris common, thin silt lenses and wisps common from 939-937; locally a black mudstone; appears locally bioturbated, black plant flecks often concentrated in thin laminae and lenses, local very fine sandstone lenses near top.
942 - 944	Phylloid algal biomicrudite, gray; large algal blades throughout, broken algal mat laminations on top, local intraclasts; appears locally bioturbated.

APPENDIX 3 (Contd.)

Depth in Feet	
944 - 946	Crinoid biomicrudite, dark gray; locally silty, algal blades common, may contain uneven algal mat laminae near top; silty near top; appears locally bioturbated.
946 - 946.5	Fusulinid biomicrite, dark gray; abundant crinoid debris, local intraclasts, local spar; appears bioturbated; well sorted allochems; crinoid debris becomes more abundant toward the top, fusulinids become less abundant toward the top.
946.5 - 956.5	Phylloid algal biomicrudite, locally a fossiliferous micrite, gray; large phylloid algal blades throughout, black organic laminations and wisps locally throughout; appears bioturbated; local intraclasts, crinoid debris throughout.
956.5 - 959	Silty fossiliferous micrite, gray to dark gray; crinoid, brachiopod, and algal debris; local black laminae; well indurated; black plant flecks common, gray silty laminae throughout; becomes a calcareous siltstone in upper part, then grades into a phylloid algal biomicrudite.
959 - 965	Calcareous siltstone, gray to dark gray; unevenly laminated, local crinoid debris; abundant black laminae may be algal mat laminations; local silty fossiliferous micrite zones, flecks of black plant debris throughout, local phylloid algal blades.
965 - 968.5	Silty biomicrudite, local phylloid algal concentrations, dark gray; abundant black laminae may be algal mat laminations, local zones of high silt concentration; local well indurated phylloid algal biomicrudite; crinoid debris common, appears bioturbated locally.
968.5 - 971	Calcareous siltstone, gray to dark gray; unevenly laminated, local crinoid debris; local concentrations of black laminae may be algal mat laminations; generally well indurated; is locally a silt-rich fossiliferous micrite, flecks of black plant debris common throughout.
971 - 984.5	Silty phylloid algal-crinoid biomicrudite, gray; appears bioturbated; large crinoid columnals common, local sparry zones, ferrugenous stain common, local silt-rich zones, local fine black organic flecks

APPENDIX 3 (Contd.)

Depth in Feet	
971 - 984.5	throughout, small intraclasts common; is locally a fossiliferous, calcareous siltstone; generally well indurated.
984.5 - 994.5	Calcareous, siltstone, highly fossiliferous, dark gray; local zones of black organic material; phylloid algal, crinoid, brachiopod debris throughout; zones up to 4 inches thick of silty phylloid algal biomicrudite; unit laminated to bioturbated, possible algal mat laminations, unit is locally platy to fissile where silt is abundant, large crinoid columnals common; zones of silty fossiliferous micrite with phylloid algal debris are common; unit is locally well indurated where micrite is dominant over silt.
994.5 - 998.5	Phylloid algal biomicrudite, gray; local spar, crinoid debris, intraclasts; appears locally bioturbated.
998.5 - 999	Silty crinoid biomicrudite, dark gray; large crinoid columnals throughout, phylloid algal blades common.
999 - 1006	Phylloid algal biomicrudite, gray; local sparry zones throughout, crinoid debris common, local intraclasts; appears locally bioturbated; local flecks of black organic debris.
1006 - 1007	Calcareous siltstone, gray; laminated, crinoid and fenestrate bryozoan debris, possible local algal mats; one rugose horn coral noted.
1007 - 1007.5	Phylloid algal biomicrudite, gray; local sparry zones, large algal blades up to 1.5 inches across; algae was locally killed by influx of overlying calcareous silt.
1007.5 - 1009	Calcareous siltstone, gray; laminated to bioturbated, crinoid and fenestrate bryozoan debris common, flecks of black plant debris throughout; local brachiopods.
1009 - 1024.5	Phylloid algal biomicrudite, gray; local crinoid debris, local sparry zones, local micritic intraclasts; appears bioturbated; local laminated black organic zones may be algal mats; local stylolites; laminated black organic silty zones up to 1 inch thick common in upper 2 feet; fewer phylloid algal blades in upper 2 feet; local brachiopods and fenestrate bryozoa in silty zones.

APPENDIX 3 (Contd.)

Depth in Feet	
1024.5 - 1026	Packed intraclastic biomicrite with local spar, gray; crinoid, fusulinid, brachiopod debris; local black organic debris, local intraclasts up to 1 inch across; generally well sorted bioclastic debris; intraclasts rounded to squeezed and composed of muddy silt with shelly debris (material of underlying unit).
1026 - 1028	Calcareous silty mudstone, gray; laminated to heavily bioturbated; abundant crinoid, brachiopod, and bryozoan debris throughout, fenestrate bryozoans common; becomes increasingly calcareous upward; fusulinids and phylloid algal blades common near top.
1028 - 1041	Silty mudstone, gray to dark gray; interlaminated gray silt and dark mud, uneven to wispy; locally bioturbated; rich in fine black plant debris which is often concentrated in lenses and thin zones; local thin zones rich in crinoid and brachiopod debris; unit becomes increasingly silty, shelly and bioturbated upward; top of unit is a muddy siltstone with abundant crinoid and other skeletal debris.
1041 - 1058.5	Mudstone, dark gray to black with abundant red ferrugenous lenses and nodules; laminated, platy to fissile, local small crinoid debris, local small orthocone cephalopods, local wispy silt laminae, fine plant debris common; appears bioturbated locally; local fine pyrite crystals.

MOBIL CORE HOLE NO. 11
NW Wise County, Texas
(Designated Core Hole #3, This Report)

772 - 779.5	Silty mudstone with abundant red ferrugenous lenses and concretions; thin silt laminae abundant throughout; platy; plant debris noted.
779.5 - 790	Sandstone, very fine to fine grained, light gray; abundant fine black plant debris throughout; appears homogenous; thin wispy zones of plant debris, local thin mudstone zones; appears laminated to rippled toward the top, same basic grain size throughout, does not appear to coarsen or fine upward or downward.

APPENDIX 3 (Contd.)

Depth in Feet	
790 - 790.5	Sandy silty mudstone, gray to black; ferrugenous lenses, rich in black organic debris.
790.5 - 792	Sandstone, very fine to fine grained, light gray; abundant black plant debris in zones, local ferrugenous clay chips, local small penecontemporaneous faults, homogenous to locally laminated; thin mudstone drapes locally.
792 - 793	Silty sandstone, very fine grained, gray; abundant black plant debris often concentrated in zones; appears laminated; gradational above and below.
793 - 803.5	Silty mudstone with abundant reddish ferrugenous claystone lenses and concretions, gray to black; abundant plant debris, platy to fissile; silt content increases upward; unevenly laminated and wispy throughout.
803.5 - 805	Silty sandstone, very fine grained, gray; rich in black plant debris and mud chips; laminated to wispy, to homogenous; local ferrugenous mudstone lenses up to 1.3 inches thick.
805 - 809.5	Silty mudstone with abundant reddish ferrugenous claystone lenses and nodules, gray to black; abundant plant hash throughout, numerous thin silty zones and wisps.
809.5 - 812	Silty sandstone, very fine grained, gray; abundant black plant debris, silty clay chips common; appears somewhat laminated to homogenous; base appears gradational; wisps of organic debris and mud common, local ferrugenous claystone nodules, thin mudstone zones.
812 - 830	Silty mudstone with reddish ferrugenous claystone lenses and nodules, dark gray to black; abundant plant stems and leaves up to several inches across; well laminated, platy to fissile; silt and very fine sand zones up to 3 inches thick; locally bioturbated; silt zones increase in number upward, silts appear locally contorted to slightly rippled, silts occur in thin lenses and pods.
830 - 830.5	Organic-rich siltstone, gray; abundant black plant debris; laminated to homogenous; almost a coal locally.

APPENDIX 3 (Contd.)

Depth in Feet	
830.5 - 833	Mudstone, black; abundant plant material throughout; platy to fissile, laminated; 1 inch thick red ferrugenous claystone lens on top.
833 - 833.5	Phylloid algal biomicrudite, gray; increasing terrigenous mud toward the top; crinoid debris common, algal blades up to 1.3 inches across.
833.5 - 840	Crinoid-fusulinid biomicrite, gray to dark gray; thin zones of organic-rich silts; fenestrate bryozoans common; grades into a packed crinoid biomicrite with local spar, this grainstone facies is well sorted; abundant algal blades.
840 - 845.5	Crinoid biomicrite, gray; thin terrigenous silty zones; a fine skeletal debris in a micrite matrix; local small horn corals and fusulinid concentrations, bioturbated, may be algally laminated locally, local thin wisps of black organic debris; locally becomes a fossiliferous micrite.
845.5 - 852.5	Phylloid algal biomicrudite and biomicrite, gray; abundant crinoids, thin terrigenous mud zones, appears silty, wisps of black organic debris; locally a crinoid biomicrudite; locally an algally laminated biomicrite; a platy-fissile fossiliferous, silty mudstone from 846 to 846.5.
852.5 - 853.5	Silty, muddy, crinoid biomicrudite, dark gray; high terrigenous mud content.
853.5 - 864	Phylloid algal-crinoid biomicrudite, dark gray; abundant phylloid algal blades, local terrigenous mud zones rich in black organic debris, small gastropods; appears bioturbated; may be algally laminated locally.
864 - 869	Crinoid biomicrudite, gray; local phylloid algal blades, thin organic-rich terrigenous mud zones, local intraclasts; appears bioturbated; fenestrate bryozoans common; appears silty throughout; local concentrations of large crinoid columnals; may be algally laminated locally.
869 - 876.5	Phylloid algal biomicrudite, gray; algal blades up to 1 inch across, local organic-rich mud zones up to 0.75 inch thick, crinoid debris; appears bioturbated; locally nodular in appearance; algal laminae present in thin local zones.

APPENDIX 3 (Contd.)

Depth in Feet	
876.5 - 877	Algally laminated biomicrite, dark gray; contains terrigenous mud, local crinoid debris, and local intraclasts, bryozoan fragments; grades upward into overlying unit.
877 - 879	Calcareous silty mudstone, dark gray; fissile, contains some fine skeletal and abundant plant debris; locally well indurated with sparry cement in 6 inch zones; crinoidal debris increases near top; laminated to bioturbated.
879 - 879.5	Muddy phylloid-algal biomicrudite, dark gray to black; algal flakes up to 0.5 inch across, local crinoid debris, local algal laminations, fusulinids common; grades upward into a crinoid biosparite.
879.5 - 885	Silty mudstone, dark gray; fissile, contains some fine skeletal debris and what appear to be small worm tubes; fine, macerated plant debris common; local small pelecypod valves; locally laminated to bioturbated.
885 - 885.5	Fossiliferous sparite, dark gray; terrigenous mud content increases upward; contains some black organic debris; may be an inversion texture; appears homogenous to bioturbated; local coated grains and oolites.
885.5 - 890.5	Fusulinid biosparite, gray; fusulinids appear to show preferred orientation; very well indurated, some crinoid debris, well sorted; grades upward into crinoid-fusulinid biosparite with local small intraclasts, appears well sorted and well winnowed; local oolite and coated grain concentrations.
890.5 - 893	Silty, muddy, fusulinid biomicrite; nodular to churned, abundant small fusulinids, isolated small horn corals not in growth position, crinoidal debris, possible algal stromatolites locally; unit nodular in appearance; interbedded lime mud and spar become increasingly abundant upward; local phylloid algae.
893 - 900.5	Packed phylloid algal biomicrudite, gray; algal flakes up to 0.75 inch across; thin silty-muddy partings abundant, local silty wisps; appears heavily bioturbated locally; plant debris in silty-muddy zones; local thin intraclastic zones.

APPENDIX 3 (Contd.)

Depth in Feet	
900.5 - 901	Fossiliferous mudstone, dark gray; abundant fine skeletal and black organic debris in a dark mud matrix; well cemented; local black mud zones; homogenous to laminated.
901 - 902	Siltstone, muddy, gray; bioturbated; local shelly debris increasing near top, local plant debris.
902 - 902.5	Siltstone, muddy, gray; plant debris, laminated, fissile.
902.5 - 904	Fossiliferous mudstone, dark gray; abundant fine skeletal and black organic debris in a dark mud matrix; well indurated, appears laminated; local isolated intraclasts, fine skeletal debris is generally well sorted; some local brachiopod debris up to 1 inch across; plant debris in this zone.
904 - 904.5	Siltstone, muddy, gray; abundant plant debris; laminated, fissile.
904.5 - 906	Intraclastic calcareous mudstone, dark gray; dense, well indurated; abundant plant hash; appears laminated to bioturbated; local skeletal debris.
906 - 907.5	Siltstone, gray; local lenses of shell hash, abundant plant debris; laminated to wispy; some plant material several inches across.
907.5 - 910.5	Fine biosparite, gray; numerous thin muddy zones and wisps, local pockets of black organic debris; grades upward into a laminated calcareous mudstone in upper 1 foot; local coated grains and oolites.
910.5 - 913	Silty mudstone, gray; laminated to wispy, fissile; locally squeezed; abundant fine plant hash in thin lenses.
913 - 915.5	Intraclast-rich biosparudite, gray; intraclasts up to 1 inch across, abundant crinoid and brachiopod debris; allochem size increases upward; poorly sorted; thin, muddy organic-rich zones throughout; may be bioturbated.
915.5 - 916.5	Plant-rich biosparite, gray; fine crinoid and shelly debris, abundant black plant material up to several inches long; dense, very well indurated; local coated grains and oolites.

APPENDIX 3 (Contd.)

Depth in Feet	
916.5 - 917	Intraclastic biomicrite, gray; abundant fine crinoid hash; lenses and wisps of black plant material.
917 - 1057.5	Mudstone, dark gray to black with red ferrugenous clay lenses and nodules; platy to fissile; local orthocone cephalopod debris, ferrugenous nodules up to several inches across, local crinoid columnals, local fusulinids, local small pyrite crystals; locally bioturbated; appears rich in black organic material, occasional pelecypod valves, local small brachiopods; silty zone from 953 to 949.5 with few ferrugenous lenses; local thin lenses of black organic detritus in upper several feet; unit becomes more silty and shows a pronounced increase in plant material in upper 20 feet; somewhat calcareous toward top.
1057.5 - 1058	Highly fossiliferous silty mudstone, black; abundant, sorted crinoid columnals intermixed with black silty mud; thin ferrugenous zones; appears to be of debris flow origin.
1058 - 1066	Mudstone, dark gray to black with red ferrugenous zones and nodules; platy to fissile, local thin silt laminae; appears homogenous and locally bioturbated; local small crinoid columnals.
1066 - 1066.5	Highly fossiliferous silty mudstone, dark gray to black; bioturbated; brachiopod, crinoid, gastropod, pelecypod debris generally less than 2 mm. across; one pelecypod valve 0.75 inch across; local pyrite crystals.
1066.5 - 1069	Mudstone, black; local thin silt laminae, platy to fissile; local black organic flecks appear to be plant debris, local small crinoid columnals; appears bioturbated.
1069 - 1071	Highly fossiliferous silty mudstone, dark gray to black; unevenly laminated; crinoid, brachiopod, fusulinid debris, all of which is broken.
1071 - 1072.5	Fine fossiliferous sparite, tan, rich in black organic flecks; appears inverted; local stylolites, some crinoid and fusulinid debris up to 1 mm. across; becomes muddy toward the top and grades into next overlying unit; abundant coated grains.

APPENDIX 3 (Contd.)

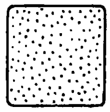
Depth in Feet	
1072.5 - 1074.5	Sparry micrite, light gray to white, birdseye texture; appears heavily bioturbated, no original structure remains; flecks of black organic debris throughout, one coiled nautiloid 0.6 inch across noted; may have been subaerially exposed and weathered.
1074.5 - 1084	Fine biosparite, light gray to white; dense, appears bioturbated and is obviously inverted; high porosity; appears almost sucrosic locally; local non-inverted zones of finer spar and micritic material; porosity increases upward; vuggy and dolomitic near top, appears weathered or highly leached; spongecake texture in upper 3 feet; local coated grains.
1084 - 1084.5	Algal-crinoid biomicrite, light gray; dense, well sorted skeletal debris; local wisps of black organic material.
1084.5 - 1086	Mudstone, black; abundant crinoid debris and flattened black mudstone intraclasts up to several inches across; poorly sorted; appears to be a turbidite or ripup zone; local wisps of black organic material; grades upward into next overlying unit.
1086 - 1095.5	Mudstone, dark gray to black with abundant red ferrugenous mudstone concretions and thin ferrugenous zones (average 0.3 inch thick); fissile, local silty wisps throughout, unconsolidated; rich in fine, black organic material; locally squeezed in appearance; upper 2 ft. laminated black mudstone.
1095.5 - 1108	Silty mudstone, dark gray; well laminated to wispy; locally bioturbated; abundant gray silt laminae throughout, locally slightly contorted; local Pectin-like pelecypod impressions up to 0.75 inch across; local plant debris up to several inches across; local pyrite nodules up to 0.4 inch across.
1108 - 1125.5	Mudstone, dark gray to black with abundant red ferrugenous mudstone laminations and concretions; well laminated, local fine silt laminae, platy to fissile; local fine pyrite crystals; rich in black organic material; appears locally squeezed.

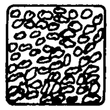
APPENDIX 3 (Contd.)

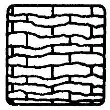
Depth in Feet	
1125.5 - 1142	Silty mudstone, calcareous, gray to black; laminated to wispy, dense, local small crinoid columnals, abundant fine plant debris; local poorly sorted bioclastic zones up to 0.75 inch thick; locally bioturbated; fine skeletal debris throughout; local fusulinids; local fine pyrite crystals.
1142 - 1143.5	Intramicrudite in silty mudstone, dark gray; brecciated carbonate zones up to 3.5 inches thick, separated by dark gray to black silty mudstone; carbonate fragments are micritic and are angular and poorly sorted, fragments up to 0.75 inch across, average 0.5 inch across; abundant crinoid debris intermixed; underlying silty mudstone appears slightly sworled and contorted.
1143.5 - 1153	Silty mudstone, dark gray; laminated to wispy; abundant thin, gray silt laminae and wisps, locally pyritic, abundant fine macerated plant debris, local red ferrugenous mudstone concretions and laminations, thin laminae of black plant debris throughout; may be locally bioturbated; generally very rich in black organic material.

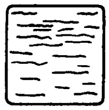
APPENDIX 4

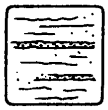
Symbols Used In Measured Section Diagrams (Refer to Plates II and III) and a Note Concerning the Preparation of Surface Stratigraphic Sections

Sandstone 

Conglomerate 

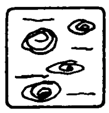
Limestone 

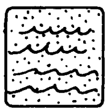
Silty shale 

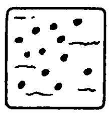
Silty, sandy shale 

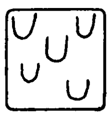
Trough cross stratification 

Squeezed, contorted sandstone 

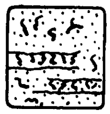
Flow-roll structures 

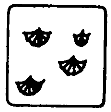
Ripple bed forms 

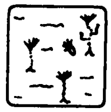
Ferrugenous nodules 

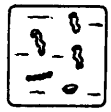
Erosional channels 

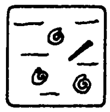
APPENDIX 4 (Contd.)

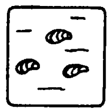
Burrowed sandstone 

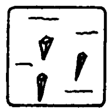
Brachiopods 

Crinoids 

Sponges 

Nautiloids 

Myalina sp. 

Conularians 

NOTE: The surface stratigraphic sections (Plates II and III) are based on measured sections at selected locations along strike in the Wolf Mountain and Placid Shale Formations respectively. Locations of measured sections are shown on the Geologic Map (Plate I) and are described in Appendix 1. In each surface stratigraphic section (Plates II and III) the measured sections were projected perpendicularly into a line of section which parallels present day structural and inferred original depositional strike.

APPENDIX 5

NET SANDSTONE AND NET LIMESTONE VALUES IN FEET

FOR WELLS USED IN SUBSURFACE MAPPING--LISTED BY COUNTY

Refer to Plates

Plate IV - Net sandstone for Wolf Mountain Formation

Plate V - Net limestone for Winchell Limestone

Plate VI - Net sandstone for Placid Formation

Plate VII - Net limestone for Ranger Limestone

Plate VIII - Net sandstone for Colony Creek Formation

Plate IX - Net limestone for Home Creek Limestone

--- means that the interval was not logged.

Canyon Interval Massive Limestone - means that the entire Canyon Group stratigraphic interval is massive carbonate.

Canyon Interval Limestone and Shale - means that the entire Canyon Group stratigraphic interval is massive carbonate with shale breaks throughout.

X+ - means that the entire interval was not covered by the log, and, therefore, the sandstone or limestone count is not complete.

CH - means Core Hole designations in northwestern Wise County.

NR - means that the interval was not reached by the well bore.

Ls - means that the interval is represented by massive limestone.

NOTE: Well names and depths by county are listed on open file at the Bureau of Economic Geology, 5th floor, Geology Building, The University of Texas at Austin, Austin, Texas.

APPENDIX 5 (Contd.)

ARCHER COUNTY

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
1	75	3	10	23	70	14
2	65	0	0	30	30	15
3	30	5	0	23	95	40
4	100	3	0	18	115	35
5	100	0	15	25	35	42
6	80	0	5	35	35	37
7	50	10	0	35	25	40
8	30	0	0	40	0	50
9	25	0	0	44	40	48
10	25	3	0	52	30	45
11	20	8	55	0	45	48
12	75	2	0	23	15	55
13	15	0	20	30	5	33
14	60	2	0	40	35	50
15	30	0	0	52	40	42
16	35	0	0	55	40	32
17	20	0	5	18	10	32
18	15	4	10	30	5	33
19	40	0	0	53	5	45
20	50	5	10	23	10	38
21	95	0	30	15	23	37
22	30	5	10	20	15	50
23	35	8	5	35	10	50
24	65	0	15	23	58	55
25	80	5	35	5	15	95
26	50	0	35	3	0	110
27	50	0	25	3	15	140
28	35	3	15	8	5	110
29	45	0	10	3	20	100
30	20	0	5	5	15	90
31	40	0	10	0	0	85
32	20	4	5	6	5	100
33	10	4	20	3	0	75
34	15	4	5	8	0	120
35	15	5	5	8	10	90
36	15	0	5	12	10	122
37	25	0	5	8	5	120
38	25	3	15	3	33	46
39	20	0	5	1	108	38
40	30	3	53	4	62	41
41	30	6	35	8	20	40
42	25	10	25	0	50	32
43	20	8	30	0	90	23

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
44	30	0	25	0	100	25
45	35	5	50	0	10	28
46	15	20	33	3	45	42
47	25	70	20	0	70	60
48	10	53	5	10	0	33
49	20	80	10	5	80	36
50	40	5	60	0	50	36
51	35	0	80	0	40	40
52	15	0	5	12	5	33
53	30	0	30	0	5	12
54	35	5	0	0	0	130
55	15	0	0	0	75	8
56	15	0	0	0	20	12
57	15	0	0	0	0	110
58	10	4	25	0	0	90
59	20	0	0	0	0	85
60	15	10	15	0	0	80
61	10	12	22	10	5	70
62	12	5	15	3	25	35
63	30	5	40	0	20	30
64	15	5	35	5	5	25
65	30	12	50	0	130	25
66	40	5	25	0	38	30
67	45	4	10	0	40	30
68	10	4	5	0	55	28
69	0	10	0	0	185	100
70	15	5	0	5	0	60
71	30	5	40	0	0	70
72	25	5	0	5	30	65
73	10	8	0	4	20	45
74	30	3	0	2	35	20
75	20	20	5	0	50	20
76	30	20	5	0	35	20
77	20	70	0	3	35	15
78	20	10	20	5	25	15
79	15	60	0	0	25	18
80	75	60	15	0	100	15
81	40	15	0	0	50	20
82	45	5	0	0	45	20
83	20	3	10	5	85	15
84	40	8	5	0	50	47
85	30	6	10	0	85	42
86	30	12	12	3	77	40
87	25	5	35	0	15	60
88	25	5	45	0	25	65
89	30	2	25	0	85	78
90	0	6	0	2	255	5

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
91	0	20	0	0	205	68
92	20	10	20	0	58	75
93	10	18	15	0	125	80
94	0	5	0	0	205	65
95	0	0	0	0	285	5
96	0	5	0	0	245	15
97	0	0	0	0	285	15
98	5	0	70	15	100	15
99	20	0	20	3	55	15
100	0	3	0	8	215	5
101	0	0	0	0	180	5
102	0	12	0	0	235	5
103	0	0	0	0	175	8
104	0	0	0	0	295	4
105	0	0	0	0	290	4
106	0	12	0	0	340	5
107	0	15	0	0	275	10
108	0	10	0	4	255	12
109	0	0	0	0	330	6
110	30	5	50	0	110	10
111	0	0	0	0	175	5
112	0	10	0	0	150	15
113	40	45	25	20	55	15
114	0	0	0	15	125	13
115	20	12	0	10	35	12
116	15	5	10	15	20	10
117	0	0	0	10	230	10
118	0	0	0	0	435	10
119	0	0	0	0	360	5
120	0	0	0	5	365	15
121	100	40	80	4	160	5
122	0	0	0	0	370	3
123	40	0	50	0	180	10
124	40	6	10	0	120	20
125	35	4	15	0	30	70
126	25	0	20	0	55	70
127	35	8	0	0	50	75
128	25	0	0	0	60	55
129	25	0	10	0	25	60
130	70	0	30	5	15	25
131	140	5	0	12	130	10
132	70	0	20	0	95	8
133	80	32	35	5	150	8
134	40	4	10	4	40	60
135	15	0	40	0	85	60
136	30	0	40	0	75	30

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
137	35	0	30	3	60	20
138	35	0	50	0	130	25
139	35	0	50	0	120	40
140	60	4	40	0	110	25
141	70	6	40	0	75	30
142	85	3	60	0	60	20
143	30	10	5	3	45	18
144	30	5	0	0	35	18
145	45	12	15	0	100	15
146	45	10	25	2	150	12
147	30	5	28	0	135	5
148	40	10	20	0	148	12
149	35	0	30	0	220	12
150	25	5	35	3	185	12
151	0	3	0	0	360	6
152	0	0	0	0	405	5
153	45	0	30	0	150	15
154	60	0	60	0	210	15
155	50	0	60	5	185	10
156	60	0	170	0	210	5
157	230	0	150	0	240	8
158	250	0	60	20	140	4
159	30	30	0	20	150	4
160	120	35	0	15	210	3
161	205	35	0	0	210	5
162	60	0	20	15	205	0
163	115	0	30	5	165	10
164	80	5	50	15	170	3
165	15	0	60	15	150	4
166	40	0	0	50	45	40
167	65	0	0	30	30	30
168	80	0	0	30	40	18
169	100	4	0	35	45	35
170	75	0	0	32	60	35
171	25	0	25	15	15	40
172	5	0	0	45	0	50
173	15	0	0	60	0	60
174	15	0	0	45	20	40
175	20	8	0	45	0	40
176	25	0	0	70	40	30
177	20	0	0	55	70	15
178	10	0	0	90	40	20
179	25	20	30	0	45	25
180	15	20	0	0	35	15
181	10	0	0	0	90	20
182	10	0	15	0	105	15

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
183	10	0	10	0	120	40
184	15	0	25	0	145	15
185	70	0	60	8	160	10
186	15	0	15	8	20	50
187	10	0	10	10	45	60
188	140	0	20	20	25	55
189	190	0	25	27	25	80
190	---	---	---	---	0	90
191	95	0	40	5	10	75

BAYLOR COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	30	0	10	20	65	8
2	30	0	8	20	40	7
3	25	0	20	0	28	32
4	15	0	20	0	105	5
5	20	0	10	10	85	12
6	25	0	8	15	90	10
7	20	0	5	0	125	8
8	25	0	23	0	100	17
9	10	0	0	4	90	22
10	10	4	0	4	65	15
11	10	25	0	0	45	45
12	10	13	12	3	78	20
13	15	0	20	0	110	20
14	10	8	45	0	70	23
15	25	0	18	0	50	19
16	30	6	5	12	37	8
17	10	3	5	0	20	47
18	15	0	40	18	15	33
19	30	0	15	0	65	25
20	10	0	15	10	115	17
21	15	5	0	15	130	5
22	30	5	15	0	90	8
23	35	5	5	10	165	5
24	15	10	10	10	115	2
25	20	0	10	5	95	6
26	50	0	20	0	25	10
27	5	27	15	12	145	2
28	0	57	50	0	185	5
29	25	0	20	8	130	3
30	10	0	25	4	130	5
31	Canyon	Interval	Massive	Limestone		
32	---	---	---	10	120	18
33	Canyon	Interval	Massive	Limestone		

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
34	Ls	Ls	0	45	50	8
35	50	30	0	8	215	5
36	Canyon	Interval	Massive	Limestone		
37	Canyon	Interval	Massive	Limestone		
38	Canyon	Interval	Massive	Limestone		
39	Canyon	Interval	Massive	Limestone		
40	10	23	8	3	130	0
41	Canyon	Interval	Massive	Limestone		
42	Canyon	Interval	Massive	Limestone		
43	Canyon	Interval	Massive	Limestone		
44	Canyon	Interval	Limestone	and Shale		
45	0	0	0	65	55	8
46	20	18	10	5	120	5
47	25	20	0	70	70	12
48	Canyon	Interval	Massive	Limestone		
49	Canyon	Interval	Limestone	and Shale		
50	5	0	5	10	15	150
51	Canyon	Interval	Massive	Limestone		
52	Ls	Ls	5	5	135	0
53	20	10	15	7	115	0
54	25	0	40	0	105	5
55	15	3	20	3	55	10
56	25	0	17	0	90	3
57	15	0	5	13	80	5
58	30	3	20	18	80	10
59	15	0	5	0	80	10
60	0	0	5	0	90	12
61	25	0	15	10	90	0
62	10	6	27	10	150	10
63	15	5	70	0	85	18
64	20	3	50	0	90	13
65	30	0	45	0	140	13
66	30	0	40	8	85	18
67	10	4	20	8	155	18
68	25	10	5	5	125	10
69	25	0	20	20	95	22
70	---	---	40	15	55	35
71	5	0	70	6	25	23
72	5	0	35	10	35	15
73	15	0	45	0	50	15
74	0	0	50	0	0	40
75	0	0	20	8	18	35
76	20	12	12	0	105	20
77	25	0	55	0	95	10
78	20	15	50	30	160	5
79	30	2	15	0	110	4
80	20	6	15	0	105	12

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
81	30	5	12	22	65	20
82	Canyon	Interval	Massive	Limestone		
83	30	12	0	3	88	25
84	5	15	23	0	110	18
85	20	8	110	0	20	22
86	25	5	0	12	70	12
87	30	0	20	8	28	18
88	30	0	45	5	100	25
89	5	0	15	5	10	22
90	20	0	25	78	20	15
91	15	0	45	150	0	35
92	20	0	110	0	70	20
93	5	0	0	0	160	15
94	25	0	15	0	35	10
95	25	0	0	0	115	8
96	55	0	5	15	70	110
97	115	0	0	12	80	80
98	150	0	5	0	45	80
99	30	0	10	18	5	12
100	15	0	0	0	90	10
101	15	0	15	2	105	8
102	50	0	0	0	50	25
103	5	0	80	0	45	24
104	5	0	10	0	35	18
105	10	0	110	0	25	8
106	15	0	0	0	25	27
107	15	0	5	3	20	35
108	20	0	35	4	25	20
109	40	10	20	10	70	8
110	20	0	25	10	15	22
111	10	2	5	0	135	3
112	0	0	0	25	15	30
113	10	0	40	0	60	23
114	15	10	35	0	140	8
115	10	20	0	3	145	0
116	10	3	0	22	225	0
117	Canyon	Interval	Massive	Limestone		
118	0	3	15	7	70	10
119	20	5	15	0	65	13
120	10	5	10	0	40	37
121	15	0	15	0	30	8
122	10	0	10	5	30	5
123	15	0	5	10	50	8
124	10	0	0	0	70	8
125	5	0	0	8	5	60
126	10	0	15	0	75	8

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
127	30	0	40	0	80	10
128	20	0	20	0	120	10
129	30	15	45	5	75	10

CLAY COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	40	0	85	20	45	3
2	125	0	95	35	45	5
3	55	10	90	40	60	0
4	100	3	75	23	30	13
5	120	0	85	18	20	0
6	120	0	130	40	20	12
7	85	5	65	50	5	22
8	90	0	50	65	10	8
9	135	0	105	75	10	18
10	140	0	40	65	5	20
11	90	0	45	55	5	10
12	170	0	95	35	5	8
13	125	0	105	35	55	10
14	125	10	60	35	20	12
15	180	3	35	50	40	13
16	65	0	45	45	20	0
17	95	10	40	80	10	25
18	120	0	45	76	23	20
19	45	0	40	65	25	20
20	80	4	35	83	25	20
21	80	2	58	77	18	30
22	45	10	5	70	15	18
23	20	23	35	65	50	10
24	50	8	45	65	27	35
25	115	0	25	70	30	18
26	30	30	15	70	55	27
27	65	12	25	50	40	10
28	70	10	0	15	38	10
29	70	0	15	59	45	10
30	50	7	0	20	35	10
31	35	5	50	45	40	10
32	35	5	50	70	45	12
33	35	10	30	50	15	12
34	25	5	15	16	25	14
35	20	8	75	80	40	30
36	15	3	15	18	35	12
37	30	3	40	65	30	13
38	20	2	15	10	22	12

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
39	30	0	45	60	15	15
40	65	20	20	45	15	22
41	50	15	35	55	15	5
42	60	10	35	65	5	5
43	185	7	20	60	25	5
44	165	0	50	60	20	10
45	140	5	40	70	15	3
46	165	3	45	70	30	5
47	130	0	42	65	20	20
48	85	0	45	70	10	25
49	165	0	15	70	15	25
50	125	5	38	60	13	27
51	135	0	40	60	5	22
52	65	5	15	18	10	22
53	100	10	60	60	20	25
54	65	0	10	15	5	20
55	30	30	40	8	10	3
56	0	60	10	15	10	8
57	30	40	40	8	5	10
58	100	13	35	60	55	27
59	140	0	95	70	10	25
60	75	15	20	60	80	33
61	90	0	50	70	30	32
62	150	0	40	65	30	20
63	110	12	30	30	48	5
64	140	0	60	35	15	25
65	185	0	87	22	30	30
66	145	4	20	15	50	33
67	165	10	40	8	35	22
68	100	5	20	0	40	30
69	95	10	10	12	10	35
70	90	15	20	15	15	30
71	40	10	27	45	15	35
72	20	0	0	15	10	28
73	60	5	0	12	10	8
74	25	10	0	20	0	12
75	27	10	10	8	10	20
76	15	30	5	8	0	15
77	15	30	5	15	10	20
78	90	4	10	35	5	30
79	100	3	5	10	15	25
80	100	2	0	12	20	22
81	30	35	10	10	5	20
82	30	23	15	15	10	18
83	30	25	15	12	10	15
84	15	100	25	20	15	8

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
85	15	40	10	15	20	6
86	30	20	15	10	10	12
87	25	6	20	12	20	10
88	20	0	40	10	20	18
89	58	0	40	20	20	6
90	40	0	25	25	60	6
91	---	---	---	---	65	3
92	120	0	10	4	25	30
93	150	3	25	0	40	30
94	390	4	20	15	40	4
95	230	0	20	10	18	8
96	210	12	25	0	20	12
97	165	12	60	5	35	7
98	90	15	75	30	35	7
99	60	30	60	10	40	10
100	90	10	90	20	55	8
101	110	13	50	5	35	10
102	180	0	80	3	45	10
103	60	0	45	18	25	4
104	125	0	50	10	40	6
105	165	4	50	20	40	30
106	70	8	15	10	70	0
107	65	6	0	20	75	0
108	40	0	60	12	125	0
109	15	6	65	12	45	2
110	25	20	10	8	40	25
111	175	0	30	6	75	0
112	490	0	150	0	111	0
113	---	---	---	---	0	12
114	200	5	200	0	35	20
115	Canyon Interval Probably Massive Limestone - NR					
116	Canyon Interval Probably Massive Limestone - NR					
117	Canyon Interval Probably Massive Limestone - NR					
118	Canyon Interval Probably Massive Limestone - NR					
119	Canyon Interval Probably Massive Limestone - NR					
120	Canyon Interval Probably Massive Limestone - NR					
121	Canyon Interval Probably Massive Limestone - NR					
122	Canyon Interval Probably Massive Limestone - NR					
123	Canyon Interval Probably Massive Limestone - NR					
124	Canyon Interval Massive Limestone					
125	Canyon Interval Probably Massive Limestone - NR					
126	Canyon Interval Massive Limestone					
127	400 Feet Sand Total for Canyon Group					
128	Canyon Interval Probably Massive Limestone - NR					
129	Canyon Interval Massive Limestone					
130	Canyon Interval Massive Limestone					

APPENDIX 5 (Contd.)

Well No.	IV	V	VI	VII	VIII	IX
	Refer to Plates					
131	Canyon	Interval	Massive	Limestone		
132	Canyon	Interval	Massive	Limestone		
133	Canyon	Interval	Massive	Limestone		
134	Canyon	Interval	Massive	Limestone		
135	Canyon	Interval	Massive	Limestone		
136	250	25	175	0	75	0
137	30	0	35	0	70	0
138	20	45	20	0	50	25
139	105	5	80	5	10	2
140	90	15	47	8	20	0
141	35	0	85	10	35	3
142	100	0	60	13	40	10
143	40	0	125	0	25	5
144	110	0	65	8	10	20
145	50	0	60	30	20	5
146	130	0	75	30	70	7
147	140	0	80	25	45	5
148	220	10	5	60	65	35
149	50	0	50	50	18	10
150	Canyon	Interval	Massive	Limestone		
151	Canyon	Interval	Massive	Limestone		
152	25	0	70	3	50	30
153	230	3	200	0	70	20
154	180	20	140	0	70	5
155	320	10	210	0	80	0
156	450	0	260	0	150	0
157	350	0	230	0	200	3
158	260	3	170	0	140	0
159	200	0	130	0	90	0
160	120	30	75	0	30	30
161	25	0	0	0	140	35
162	50	0	40	0	100	5

JACK COUNTY

1	45	15	20	25	---	---
2	80	10	55	25	---	---
3	85	10	35	27	---	---
4	45	15	20	20+	---	---
5	45	20	30	30	---	---
6	90	10	---	---	---	---
7	55	15	5	15+	---	---
8	40	10	20	32	---	---
9	230	0	5	---	---	---
10	210	5	25	18	35	15

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
11	55	4	25	40	70	15
12	40	2	45	10	100	12
13	20	8	30	12	25	5+
14	65	0	35	18	100	15
15	50	0	15	21	---	---
16	105	12	18	30	70	20
17	5	9	18	40	65	---
18	110	5	20	37	20+	---
19	15	5	40	45	---	---
20	45	8	15	40	25+	---
21	30	3	10	20	---	---
22	50	30	35	---	---	---
23	60	5	65+	---	---	---
24	10	---	---	---	---	---
25	20+	---	---	---	---	---
26	45	2	30	18	---	---
27	40	3	40	22	---	---
28	85	8	60	---	---	---
29	45+	10+	---	---	---	---
30	35	8	15	40	---	---
31	25	25	60	45	70	---
32	65	10	45	30	---	---
33	55	5	50	30	55	12
34	110	170+	---	---	---	---
35	60	170+	---	---	---	---
36	30	---	---	---	---	---
37	40	110+	---	---	---	---
38	35	20+	---	---	---	---
39	65	5	---	---	---	---
40	35	165+	---	---	---	---
41	68	---	---	---	---	---
42	25	---	---	---	---	---
43	50	160+	---	---	---	---
44	60	35	40	40	40	12
45	53	---	---	---	---	---
46	90	0	35	15	15	15
47	70	5	50	20	150	0
48	45	15	40	22	18	20
49	60	15	20	20	33	15
50	40	8	45	25	30	18
51	160	8	23	45	15	10
52	25	6	27	35	15	5
53	50	12	35	33	20	13
54	130	20	15	60	50	15
55	100	30	15	15	75	13
56	25	15	18	50	70	15

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
57	60	10	8	37	40	8
58	55	7	20	40	30	10
59	75	5	20	36	55	10
60	80	7	10	55	30	10
61	60	10	10	20	45	6
62	23	10	0	25	60	10
63	40	12	15	15	155	8
64	45	10	0	30	100	6
65	45	5	10	30	60	6
66	90	2	5	20	110	10
67	120	2	5	25	110	10
68	75	0	60	55	35	18
69	50	3	90	55	20	15
70	90	0	60	55	10	15
71	100	4	85	55	30	15
72	65	3	90	45	25	12
73	75	0	55	45	15	20
74	30	3	90	30	10	8
75	132	12	70	55	15	30
76	60	0	40	60	20	12
77	30	25	25	70	50	20
78	15	25	30	50	40	10
79	60	10	10	20	55	15
80	100	7	30	65	58	18
81	120	20	60	50	35	10
82	55	40	35	50	20	15
83	78	45	15	55	5	25
84	45	40	35	55	35	25
85	95	20	0	23	105	8
86	100	10	20	50	50	15
87	140	10	0	28	35	15
88	30	3	60	33	---	---
89	100	8	30	65	35	10
90	25	5	50	55	25	10
91	40	2	45	45	23	15
92	50	6	60	42	12	8
93	80	5	60	35	40	8
94	95	3	5	22	---	---
95	42	0	20	15	35	22
96	40	8	110	30	30	5
97	120	0	90	30	25	5
98	100	2	80	4	18	18
99	70	0	130	0	35+	---
100	35	15	75	20	35	12
101	65	15	160	30	15	10
102	23	5	185	18	110	---

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
103	10	12	50	17	50	10
104	35	8	100	0	15	18
105	75	15	25	55	20	15
106	50	18	12	35	50	28
107	15	8	50+	---	---	---
108	50	0	110	18	90	5
109	35+	---	---	---	---	---
110	20	5	12	10+	---	---
111	20	5	0	45	90	18
112	10+	---	---	---	---	---
113	45	20	---	---	---	---
114	80	---	---	---	---	---
115	65	12	10	45	---	---
116	60	35	---	---	---	---
117	70	30	30	45+	---	---
118	15	95	---	---	---	---
119	85	5	75	---	---	---
120	90	18	60	35	10	30
121	60	5	50	30	30	20
122	55	0	27	22	15	15
123	50	7	27	23	25	15
124	60	15	20	30	---	---
125	25	12	45	32	---	---
126	120	5	---	---	---	---
127	60	5	---	---	---	---
128	70+	---	---	---	---	---
129	105	---	---	---	---	---
130	80	0	10	55	---	---
131	35	20+	---	---	---	---
132	15	105	155	---	---	---
133	60	5	140	15	---	---
134	60	0	25	40	---	---
135	40	8	30	50	---	---
136	95	10	27	50	25	5
137	160	25	22	20+	---	---
138	115	5	100	45	30	8
139	20	6	18	55	25	6
140	---	---	---	40	10	0
141	80	8	20	40	60	15
142	120	0	40	40	60	8
143	150	10	35	35	30	5
144	170	5	75	30	30	5
145	120	0	165	22	70	10
146	20	22	60	8	---	---
147	95	0	80	20	---	---

APPENDIX 5 (Contd.)

MONTAGUE COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	15	220	---	---	---	---
2	20	80	105	5	25+	---
3	25	18	115	15	22+	---
4	70	95	85	15	35	5
5	100	230	90	15	---	---
6	110	155	100	15	---	---
7	170	15+	---	---	---	---
8	35	200	45	20	30	5
9	60	150	50	20	25	15
10	25	95	50	25	30	12
11	20	150	60	25	20	8
12	15	100	75	15	30	8
13	40	200	30	25	20	15
14	55	150	30	30	5	7
15	55	95	75	5	10	5
16	55	90	55	15	10	5
17	10	100	40	12	5	15
18	130	45	20+	---	---	---
19	100	20	115	10	35+	---
20	70	50	25	15	10	8
21	95	45	25	3	10	5
22	95	65	35	0	35	10
23	40	30	5	3	12	5
24	65	45	35	3	45	5
25	100	45	90	8	20	0
26	80	60	75	5	12	4
27	50	70	10	12	15	5
28	15	67	10	25	16	10
29	125	60	5	12	15	8
30	30	105	25	4	30	5
31	25	90	20	2	20	8
32	120	85	50	7	25	5
33	50	95	65	4	20	8
34	95	85	10	12	20	6
35	50	80	10	12	35	6
36	40	95	10	30	15	6
37	70	135	25	25	35	6
38	25	135	25	3	20	15
39	65	80	50	10	10	15
40	80	40	85	5	25	10
41	145	45	15	3	20	2
42	55	85	35	5	25	5
43	115	40	40	0	50	0
44	175	40	60	10	25	0

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
45	45	30	15	0	45	0
46	110	20	60	0	25	0
47	165	20	10	15	50	0
48	125	25	10	8	65	0
49	100	40	15	3	60	0
50	90	20	20	5	45	9
51	75	35	20	5	25	4
52	65	75	25	25	15	5
53	125	90	15	25	15	5
54	125	108	60	18	10	6
55	120	125	50	18	25	20
56	25	170	20	0	40	12
57	50	180	30	45	20	15
58	180	85	12	93	25	10
59	130	85	0	90	27	12
60	140	45	10	83	17	10
61	175	45	5	75	25	8
62	200	25	20	65	33	6
63	205	30	12	65	15	3
64	215	23	30	60	55	4
65	210	22	15	45	50	6
66	210	25	30	55	10	12
67	225	20	30	25	65	0
68	185	15	15	35	20	15
69	200	27	80	40	60	0
70	140	45	40	35	30	0
71	130	35	30	32	130	2
72	90	25	30	20	80	3
73	70	30	28	18	120	0
74	90	25	15	12	110	2
75	120	23	20	16	90	2
76	125	5	5	10	65	0
77	155	10	20	10	70	0
78	40	12	10	8	55	0
79	85	12	5	12	38	0
80	90	5	30	5	40	6
81	125	25	25	10	65	3
82	95	0	35	8	65	0
83	175	0	90	12	50	0
84	140	10	70	3	35	0
85	110	30	40	8	65	3
86	175	55	20	14	20	4
87	200	5	65	12	55	4
88	275	0	65	12	90	5
89	125	40	45	12	75	5
90	140	25	35	15	85	5

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
91	55	35	18	18	40	5
92	25	40	70	14	70	5
93	45	45	45	12	50	6
94	30	30	50	15	60	6
95	140	25	35	12	50	10
96	110	25	40	16	50	10
97	60	22	20	10	15	8
98	28	35	35	15	10	6
99	100	20	40	13	45	10
100	130	27	35	15	15	6

PALO PINTO COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	55	50	50	30+	---	---
2	20	60+	---	---	---	---
3	20	---	---	---	---	---
4	0	90	---	---	---	---
5	15	---	---	---	---	---
6	0	100+	---	---	---	---
7	30	150	0	45	---	---
8	35	140	0	50	0	45
9	20	160	15	13	---	---
10	0	130	---	---	---	---
11	0	---	---	---	---	---
12	0	---	---	---	---	---
13	0	---	---	---	---	---
14	0	---	---	---	---	---
15	5	---	---	---	---	---
16	0	180	---	---	---	---
17	20	120+	---	---	---	---
18	70	125+	---	---	---	---
19	15	140	---	---	---	---

SHACKELFORD COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	20	0	25	12	40	20
2	80	0	0	45	10	30
3	20	0	30	10	40	25
4	15	4	10	40	28	18
5	15	10	8	22	45	45
6	45	0	10	30	40	45
7	45	0	10	100	15	35

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
8	40	0	25	60	10	25
9	25	0	25	50	60	4
10	20	0	10	35	0	37
11	60	0	0	25	0	35
12	40	60	10	25	0	47
13	10	75	0	22	35	45
14	15	12	12	70	18	25
15	60	15	0	90	18	5
16	55	25	0	90	18	5
17	30	23	0	5	5	12
18	15	0	15	0	0	45
19	20	75	0	0	5	150
20	105	80	0	0	5	135
21	35	90	0	0	5	135
22	10	180	0	0	0	140
23	15	95	0	0	35	100
24	20	0	0	0	10	95
25	10	8	20	0	12	32
26	115	0	50	3	20	33
27	22	2	5	0	20	35
28	30	130	0	100	8	45
29	0	60	0	45	0	40
30	0	0	0	65	5	50
31	0	170	0	100	27	37
32	8	140	0	120	0	65
33	75	150	0	140	0	45
34	20	150	0	130	45	40
35	15	150	0	135	18	35
36	35	160	0	130	10	30
37	40	125	0	125	0	30
38	10	140	0	130	8	35
39	0	150	0	100	10	37
40	0	170	0	110	25	55
41	27	140	0	115	12	50
42	5	150	0	100	18	37
43	0	120	0	0	0	35
44	10	90	0	0	0	90
45	35	0	25	45	0	75
46	25	140	0	125	10	65
47	30	130	0	120	0	60
48	5	130	0	115	5	60
49	12	140	0	115	5	45
50	23	140	0	130	8	40
51	10	150	0	115	8	30
52	50	115	0	45	5	30
53	42	100	0	50	0	30

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
54	0	130	5	23	12	25
55	10	150	0	120	0	50
56	0	160	0	110	0	55
57	5	155	0	130	0	90
58	15	160	0	120	5	60
59	0	120	0	---	0	155
60	20	0	33	0	15	0
61	10	0	30	2	15	4
62	10	10	5	8	10	12
63	15	15	25	5	10	28
64	10	80	0	80	5	50
65	0	90	0	100	0	50
66	20	8	10	5	0	15
67	30	8	0	3	5	10
68	30	5	5	10	0	30
69	90	0	0	5	0	40
70	0	80	0	90	5	42
71	35	140	0	130	20	30
72	0	60	0	100	0	50
73	0	110	0	30	0	45
74	10	130	0	60	10	27
75	20	140	0	70	5	35
76	60	160	0	120	22	30
77	40	170	0	110	0	15
78	30	170	0	110	30	40
79	18	160	0	140	20	30
80	15	150	0	120	5	100
81	8	175	0	100	0	50
82	50	70	0	110	15	45
83	10	150	0	100	0	45
84	20	100	5	0	0	35
85	50	0	15	55	0	55
86	20	0	0	80	10	50
87	0	35	0	10	0	12
88	10	0	5	0	40	5
89	25	5	5	3	5	15
90	25	5	5	8	10	18
91	30	0	65	12	0	35
92	15	0	30	0	0	35
93	15	0	40	0	5	45
94	30	0	8	0	40	35
95	5	0	0	0	0	120
96	35	0	0	0	0	60
97	---	---	---	---	---	35
98	30	5	8	0	35	30
99	30	20	0	25	15	25
100	40	15	0	0	70	25

APPENDIX 5 (Contd.)

Well No.	Refer to Plates IV	V	VI	VII	VIII	IX
101	35	40	0	90	20	22
102	0	50	5	25	0	105
103	0	5	0	50	30	25
104	55	0	30	60	35	30
105	---	---	5	80	20	23
106	40	0	5	90	20	18
107	35	10	0	40	25	20
108	0	10	0	25	12	40
109	15	10	0	20	15	30
110	30	10	5	15	0	25
111	25	0	0	0	0	125
112	80	50	0	0	25	115
113	70	60	0	0	22	135
114	65	0	30	0	25	30
115	35	3	25	0	10	25
116	0	3	15	0	40	30
117	40	65	0	0	0	120
118	55	12	25	0	80	12

STEPHENS COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	20	0	25	18	25	20
2	45	0	10	14	37	22
3	5	0	15	10	25	25
4	15	8	10	15	20	25
5	15	5	30	22	0	35
6	15	150	0	130	15	30
7	0	150	0	150	0	15
8	0	145	0	140	20	12
9	10	135	0	160	20	10
10	23	125	0	115	15	12
11	10	140	0	115	15	10
12	10	130	0	3	20	8
13	10	130	15	10	8	15
14	40	120	5	10	10	15
15	0	140	0	40	12	25
16	0	150	0	5	0	22
17	0	145	0	25	0	15
18	30	130	15	8	25	22
19	0	120	0	0	15	22
20	15	120	15	3	6	20
21	30	100	20	3	20	15
22	0	130	0	1	8	22
23	20	100	25	8	40	23

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
24	35	75	15	10	25	15
25	60	75	0	20	0	50
26	65	105	25	10	0	40
27	10	140	0	60	15	18
28	10	120	0	100	10	20
29	30	0	15	25	50	30
30	20	165	0	110	0	37
31	15	160	0	70	10	33
32	60	100	0	70	23	40
33	20	100	0	45	25	40
34	45	110	0	50	30	50
35	20	115	0	100	0	25
36	5	150	0	140	5	10
37	25	150	0	140	18	35
38	0	155	0	150	15	30
39	5	140	0	60	0	30
40	10	130	0	90	5	15
41	15	115	0	70	0	25
42	23	100	0	50	30	22
43	8	100	20	30	12	23
44	65	100	20	8	20	15
45	15	130	0	0	30	30
46	0	160	0	115	0	40
47	0	80	0	65	0	42
48	10	70	15	5	0	32
49	60	100	0	35	10	50
50	10	120	0	10	45	18
51	8	130	0	6	40	15
52	15	110	30	6	20	22
53	18	130	5	8	0	50
54	12	110	25	2	60	15
55	15	110	30	3	25	12
56	10	120	0	23	35	16
57	35	90	30	10	45	20
58	30	130	0	50	15	35
59	20	120	0	30	50	45
60	45	100	5	8	15	45
61	0	190	25	18	35+	---
62	35	190	12	18	5	32
63	26	180	10	7	0	32
64	20	190	0	8	20	15+
65	80	200	20	10	0	40
66	45	200	0	12	15	35
67	20	215	75	2	70	---
68	0	200	0	18	---	---
69	35	170	0	10	20	---

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
70	33	160	0	8	25	---
71	15	---	---	---	---	---
72	50	200	75	2	40	35
73	54	180	65	2	10	30
74	57	200	10	3	45	38
75	110	200	15	5	40	33
76	67	190	20	5	55	35
77	32	160	80	3	15	36
78	85	170	25	1	33	45
79	0	120	22	5	15	42
80	25	160	15	7	10	30
81	25	197	0	5	50	43
82	59	190	25	10	25	45
83	15	200	5	7	0	35
84	22	180	5	0	50	40
85	70	45	5	7	30	10
86	40	35	43	10	35	23
87	30	75	50	8	30	20
88	40	80	25	8	40	18
89	50	40	35	7	47	15
90	10	35	35	10	28	18
91	20	80	25	12	35	22
92	0	30	65	7	20	20
93	70	110	0	28	60	13
94	70	110	0	15	25	25
95	5	0	5	10	35	25
96	15	0	0	7	55	23
97	5	0	0	8	55	23
98	10	0	0	38	65	30
99	20	280	0	---	40	35
100	10	180	0	30	15	22
101	22	155	0	8	45	40
102	20	280	0	---	10	30
103	0	200	0	---	15	20
104	0	100	0	15	15	45
105	0	270	0	---	30	22
106	10	290	0	---	15	35
107	17	130	0	15	20	40
108	8	125	0	10	20	35+
109	15	130	0	50	0	20+
110	55	100	0	45	0	---
111	45	90	15	12	15	45
112	70	85	0	12	---	---
113	18	90	10	15	5	50
114	50	85	0	43	0	---
115	40	80	0	70	---	---

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
116	20	85	0	75	---	---
117	15	90+	---	---	---	---
118	65	100+	---	---	---	---
119	60	120	---	---	---	---
120	65	---	---	---	---	---
121	25	90	---	---	---	---
122	15	75	0	55	0	55
123	30	65	0	38	15	25
124	55	90	0	---	---	---

THROCKMORTON COUNTY

1	50	0	15	30	55	30
2	10	35	0	15	50	35
3	35	0	5	10	35	10
4	70	0	23	15	25	60
5	30	2	27	23	0	70
6	20	0	22	22	25	75
7	15	20	12	27	22	50
8	22	0	15	20	30	25
9	15	0	55	22	25	30
10	65	0	50	23	40	25
11	75	0	60	23	40	45
12	10	0	35	20	12	75
13	20	4	30	20	20	60
14	50	0	70	22	25	80
15	50	0	45	20	20	65
16	85	18	15	20	20	57
17	140	20	25	18	70	70
18	85	12	25	12	40	85
19	80	0	40	20	10	85
20	30	0	40	20	10	45
21	125	0	20	22	20	45
22	115	0	15	20	35	50
23	100	0	20	12	10	65
24	40	0	20	10	20	45
25	140	0	20	32	25	37
26	65	0	15	45	25	50
27	50	0	15	12	45	16
28	185	0	15	35	15	---
29	150	0	35	40	25	12
30	20	0	30	15	10	38
31	70	0	22	12	20	35
32	105	0	23	10	30	33

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
33	55	2	0	8	75	27
34	25	4	0	12	35	25
35	50	0	50	6	20	45
36	5	7	15	10	70	18
37	10	3	15	11	35	20
38	115	0	5	10	45	25
39	25	0	15	10	55	25
40	50	4	0	0	20	45
41	25	6	5	0	10	40
42	55	4	0	0	50	42
43	30	4	0	0	10	65
44	115	2	0	0	45	47
45	40	8	0	0	95	30
46	20	4	0	0	70	47
47	30	3	5	0	130	43
48	20	0	12	0	55	90
49	10	6	0	0	25	48
50	10	0	15	0	40	70
51	10	0	0	0	85	70
52	65	0	0	0	40	60
53	5	10	0	3	10	60
54	0	0	25	0	30	30
55	10	0	10	0	10	40
56	15	0	8	0	45	60
57	10	0	5	0	25	55
58	10	0	5	0	25	65
59	25	0	55	5	5	90
60	35	0	23	0	0	135
61	15	0	55	5	0	130
62	40	0	40	4	0	150
63	40	10	10	0	25	48
64	40	6	0	0	35	55
65	55	6	3	0	60	55
66	25	0	20	0	30	110
67	20	10	0	0	35	45
68	23	6	5	0	20	75
69	30	2	0	0	30	65
70	45	10	20	0	20	45
71	55	13	15	0	42	40
72	75	2	8	22	40	20
73	15	12	10	18	25	18
74	20	15	5	17	18	27
75	35	23	0	12	35	12
76	70	0	15	13	28	10
77	85	3	12	12	30	18
78	40	12	10	10	50	12

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
79	85	20	12	32	22	20
80	10	20	10	18	18	12
81	25	25	5	12	20	23
82	15	22	0	32	55	6
83	70	100	0	30	40	20
84	95	110	0	30	35	20
85	150	105	0	35	40	10
86	20	50	20	12	50	25
87	35	0	10	10	25	22
88	45	0	30	35	50	22
89	0	12	0	30	60	23
90	15	28	0	40	10	30
91	20	15	0	35	8	27
92	10	15	0	15	27	25
93	30	6	15	12	10	40
94	60	3	5	18	35	25
95	20	0	10	65	10	30
96	35	0	12	45	25	35
97	---	---	20	40	0	75
98	20	0	50	20	10	60
99	20	0	10	18	15	30
100	---	---	---	---	---	25+
101	100	0	10	27	35	15
102	0	0	10	10	10	115
103	---	---	15	20	25	12
104	10	8	0	75	15	60
105	10	10	10	3	10	100
106	25	8	0	30	8	60
107	20	0	22	10	25	15
108	32	0	25	10	35	23
109	25	18	12	23	52	18
110	---	---	---	18	18	32
111	15	5	10	20	0	40
112	30	0	15	15	65	25
113	15	0	18	10	60	35
114	18	0	15	13	65	20
115	10	0	18	15	5	32
116	40	5	15	10	50	40
117	160	12	0	40	10	30
118	15	0	10	30	70	12
119	15	5	15	12	45	20
120	100	2	20	15	20	50
121	140	0	40	12	20	55
122	75	0	75	18	40	38
123	45	0	20	45	30	30
124	30	70	10	25	50	55

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
125	60	0	30	10	20	35
126	25+	0	30	18	35	33
127	35	0	0	7	30	115
128	20	0	20	0	40	80
129	35	0	45	0	30	85
130	10	0	18	0	35	75
131	35	0	55	15	0	60
132	75	0	50	15	0	95
133	15	0	0	0	20	40
134	25	0	0	15	0	90
135	15	4	0	5	20	45
136	20	25	0	17	20	25
137	20	125	5	10	30	25
138	20	0	70	15	0	45
139	0	40	0	0	75	30
140	35	10	15	0	55	60
141	40	0	15	8	30	55
142	95	4	0	40	15	70
143	195	0	35	38	40	23
144	190	0	37	30	30	15
145	125	0	55	30	60	12
146	140	0	35	30	22	12
147	85	0	38	15	50	10
148	80	0	20	18	50	12
149	70	0	45	30	50	13
150	50	0	47	27	35	75
151	---	---	---	---	---	35
152	150	0	70	10	30	30
153	15	0	25	30	43	27

WICHITA COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	295	0	120	10	145	0
2	150	0	160	4	135	5
3	215	0	150	8	153	5
4	260	5	0	0	145	0
5	160	0	150	0	190	5
6	150	0	90	23	160	4
7	170	0	110	18	150	0
8	80	0	35	10	140	0
9	20	12	25	18	220	6
10	120	0	30	20	98	0
11	90	0	80	10	140	0
12	210	0	100	20	120	0

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
13	220	0	155	8	165	0
14	90	0	160	8	160	0
15	50	5	165	0	125	4
16	20	0	150	12	160	5
17	30	0	0	0	150	0
18	30	8	115	8	80	0
19	40	0	110	0	12	5
20	15	0	100	0	70	0
21	20	10	90	0	70	8
22	50	0	80	0	60	5
23	60	0	55	0	70	5
24	60	0	75	0	50	15
25	100	5	75	0	70	8
26	80	5	65	0	65	5
27	90	5	80	0	65	4
28	60	3	60	0	90	4
29	20	0	50	0	145	3
30	20	8	50	0	100	8
31	15	0	30	10	90	5
32	10	5	30	8	65	5
33	20	5	50	0	125	5
34	10	0	10	0	60	5
35	22	4	10	0	40	8
36	25	0	0	15	40	10
37	20	0	0	6	50	6
38	20	10	0	3	50	6
39	20	12	0	4	60	6
40	25	0	0	15	30	20
41	25	0	0	15	40	15
42	20	0	20	5	30	12
43	15	15	0	105	20	3
44	10	12	0	25	85	5
45	15	5	0	18	35	2
46	10	5	8	75	55	5
47	0	12	0	40	20	15
48	20	6	15	0	25	12
49	15	4	10	6	60	3
50	30	3	12	6	40	2
51	20	4	15	5	60	5
52	25	2	35	0	30	6
53	30	3	30	8	25	10
54	15	8	20	6	60	3
55	50	5	65	6	40	0
56	60	0	50	0	40	10
57	45	5	40	5	25	3
58	65	2	35	0	50	20

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
59	70	0	50	0	55	3
60	60	0	50	0	45	3
61	40	0	50	3	35	6
62	40	3	50	2	35	7
63	60	8	65	6	45	8
64	40	3	30	2	60	2
65	40	3	55	3	50	4
66	40	0	60	3	30	8
67	30	0	40	2	65	3
68	25	0	45	0	80	3
69	20	4	40	0	65	4
70	30	0	15	0	65	8
71	25	0	25	0	70	8
72	20	8	30	2	85	8
73	20	3	35	3	50	4
74	10	6	15	3	45	4
75	65	3	40	3	90	5
76	70	0	20	0	80	6
77	40	0	5	0	10	80
78	5	0	5	10	20	80
79	20	0	5	0	35	90
80	15	0	0	10	30	95
81	10	0	0	0	15	85
82	20	0	15	0	0	65
83	Ls	Ls	0	25	0	35
84	Ls	Ls	Ls	Ls	0	40
85	Canyon	Interval	Massive	Limestone		
86	Canyon	Interval	Massive	Limestone		
87	Canyon	Interval	Massive	Limestone		
88	Ls	Ls	0	35	0	35
89	0	0	0	3	0	43
90	Ls	Ls	Ls	Ls	0	32
91	10	15	0	0	0	45
92	Canyon	Interval	Massive	Limestone		
93	Canyon	Interval	Massive	Limestone		
94	Canyon	Interval	Massive	Limestone		
95	Canyon	Interval	Massive	Limestone		
96	0	5	0	0	90	10
97	Canyon	Interval	Massive	Limestone		
98	10	45	20	6	20	18
99	0	85	10	8	10	90
100	Canyon	Interval	Massive	Limestone		
101	Canyon	Interval	Massive	Limestone		
102	Canyon	Interval	Massive	Limestone		
103	Canyon	Interval	Massive	Limestone		
104	Canyon	Interval	Massive	Limestone		

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
105	Canyon	Interval	Massive	Limestone		
106	20	0	15	0	105	0
107	Ls	Ls	0	15	0	85
108	Canyon	Interval	Massive	Limestone		
109	Canyon	Interval	Massive	Limestone		
110	Canyon	Interval	Massive	Limestone		
111	Canyon	Interval	Massive	Limestone		
112	Canyon	Interval	Massive	Limestone		
113	Canyon	Interval	Massive	Limestone		
114	Canyon	Interval	Massive	Limestone		
115	Canyon	Interval	Massive	Limestone		
116	Canyon	Interval	Massive	Limestone		
117	Canyon	Interval	Massive	Limestone		
118	Canyon	Interval	Massive	Limestone		
119	Canyon	Interval	Massive	Limestone		
120	Canyon	Interval	Massive	Limestone		
121	Canyon	Interval	Massive	Limestone		
122	Canyon	Interval	Massive	Limestone		
123	Canyon	Interval	Massive	Limestone		
124	Ls	Ls	0	15	0	25
125	Ls	Ls	0	8	0	30
126	---	---	---	---	---	50
127	0	0	0	5	0	110
128	Canyon	Interval	Massive	Limestone		
129	Canyon	Interval	Massive	Limestone		
130	Canyon	Interval	Massive	Limestone		
131	---	---	---	---	---	25
132	Canyon	Interval	Massive	Limestone		
133	Canyon	Interval	Massive	Limestone		
134	Canyon	Interval	Massive	Limestone		

WILBARGER COUNTY

1	25	0	30	130	10	50
2	30	0	25	120	0	30
3	5	18	0	0	10	18
4	0	5	0	10	15	15
5	20	10	0	5	30	5
6	0	0	0	40	0	23
7	0	10	0	0	50	8
8	10	3	20	90	0	25
9	10	3	15	100	0	35
10	0	7	0	105	10	15

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
11	0	20	0	80	5	32
12	Ls	Ls	Ls	Ls	0	35
13	15	0	0	110	0	33
14	20	0	0	105	0	30
15	15	0	25	50	30	15
16	40	0	0	110	15	30
17	50	0	0	110	10	30
18	30	15	0	3	10	15
19	20	0	15	3	20	15
20	30	2	15	5	15	15
21	25	12	15	0	70	3
22	15	10	5	0	20	15
23	0	22	0	45	0	30
24	0	35	0	100	0	35
25	Canyon Interval Massive Limestone					
26	Canyon Interval Massive Limestone					
27	Canyon Interval Massive Limestone					
28	20	0	10	0	15	70
29	Canyon Interval Massive Limestone					
30	Canyon Interval Massive Limestone					
31	Canyon Interval Massive Limestone					
32	Canyon Interval Massive Limestone					
33	Canyon Interval Massive Limestone					
34	Canyon Interval Massive Limestone					
35	Canyon Interval Massive Limestone					
36	Canyon Interval Massive Limestone					
37	Canyon Interval Massive Limestone					
38	Canyon Interval Massive Limestone					
39	Canyon Interval Massive Limestone					
40	Canyon Interval Massive Limestone					
41	Canyon Interval Massive Limestone					
42	Canyon Interval Massive Limestone					
43	Ls	Ls	Ls	Ls	60	0
44	0	0	0	0	0	40
45	Canyon Interval Massive Limestone					
46	Canyon Interval Limestone and Shale					
47	Canyon Interval Massive Limestone					
48	Canyon Interval Limestone and Shale					
49	---	---	---	60	55	6
50	0	0	0	50	0	100
51	0	0	0	0	0	50
52	0	0	0	120	45	5
53	---	---	20	0	30	25
54	Canyon Interval Limestone and Shale					
55	Canyon Interval Massive Limestone					
56	Canyon Interval Massive Limestone					

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
57	Canyon	Interval	Massive	Limestone		
58	Ls	Ls	Ls	90	0	40
59	Canyon	Interval	Massive	Limestone		
60	0	0	0	0	20	60
61	0	0	0	120	10	4
62	Canyon	Interval	Massive	Limestone		
63	Canyon	Interval	Massive	Limestone		
64	Canyon	Interval	Massive	Limestone		
65	Canyon	Interval	Massive	Limestone		
66	---	---	10	5	0	90
67	---	---	---	---	0	12
68	0	25	0	55	10	8
69	10	10	0	25	30	8
70	25	4	50	12	50	45
71	10	0	50	0	20	90
72	15	6	100	0	115	5
73	10	20	5	8	80	12
74	30	0	10	0	0	120
75	0	20	0	0	150	8
76	80	8	70	0	55	20
77	10	15	0	5	70	10
78	10	5	10	0	25	10
79	10	10	10	10	40	5
80	10	0	40	0	25	10
81	0	20	20	5	60	8
82	30	10	0	0	95	7
83	25	15	30	0	50	10
84	0	25	20	0	30	10
85	10	0	30	5	45	12
86	5	8	10	0	15	15
87	10	4	10	4	70	10
88	20	12	80	8	20	20
89	10	0	30	12	50	10
90	Canyon	Interval	Massive	Limestone		
91	Canyon	Interval	Massive	Limestone		
92	20	25	30	4	20	10
93	15	25	5	20	15	8
94	20	25	0	25	0	20
95	20	20	0	6	35	8
96	20	20	0	10	25	10
97	55	0	0	15	40	5
98	35	4	40	3	45	7
99	20+	0	25	0	60	6
100	60	15	0	5	10	8
101	50	2	50	5	15	12
102	60	6	60	22	60	0

APPENDIX 5 (Contd.)

Well No.	IV	V	VI	VII	VIII	IX
	Refer to Plates					
103	Ls	170	0	0	40	10
104	90	0	20	8	28	10
105	10	0	30	5	10	15
106	23	0	5	4	20	15
107	0	80	0	5	12	15
108	0	35	0	10	0	18
109	30	20	0	5	18	15
110	Canyon	Interval	Massive	Limestone		
111	Canyon	Interval	Massive	Limestone		
112	0	0	0	3	0	22
113	10	0	0	0	0	55
114	0	5	0	0	0	50
115	0	0	0	3	0	40
116	0	0	0	0	0	65

WISE COUNTY

1	10	12	70	15	40	---
2	10	250	115	15	---	---
3	0	100	145	10	---	---
4	22	280	---	---	---	---
5	60	240	60+	---	---	---
6	115	200	---	---	---	---
7	50	220	---	---	---	---
8	120	200+	---	---	---	---
9	30	---	---	---	---	---
10	70	175+	---	---	---	---
11	40	250	---	---	---	---
12	50	260	---	---	---	---
13	57	240+	---	---	---	---
14	33	140+	---	---	---	---
15	0	55+	---	---	---	---
16	60+	---	---	---	---	---
17	10	40	---	---	---	---
18	35+	---	---	---	---	---
19	30	80+	---	---	---	---
20	5	35+	---	---	---	---
21	5	20	40	---	---	---
22	55	140	---	---	---	---
23	5	70	25	15	---	---
24	40	200+	---	---	---	---
25	15	15	40	---	---	---
CH1	70	150	---	---	---	---
CH2	---	60	35	15	50	8
CH3	15+	65	130	6	110	4

APPENDIX 5 (Contd.)
Refer to Plates

YOUNG COUNTY

Well No.	IV	V	VI	VII	VIII	IX
1	10	30	45	0	15	35
2	0	10	25	2	35	37
3	0	48	30	5	15	40
4	20	15	50	5	25	30
5	15	12	60	3	50	10
6	20	17	30	12	0	20
7	40	8	15	6	25	23
8	90	8	70	4	0	32
9	20	10	50	8	0	20
10	45	8	10	8	25	32
11	35	12	15	23	28	12
12	50	5	10	15	0	25
13	60	20	40	5	15	27
14	30	12	25	4	60	5
15	30	10	60	5	35	25
16	37	30	8	50	0	---
17	20	25	20	30	---	---
18	15	28	30	35	45	15
19	80	15	15	37	35	16
20	32	70	30	60	---	---
21	0	68	0	50	---	---
22	53	65	20	---	---	---
23	15	65	20	---	---	---
24	45	65	20+	---	---	---
25	27	75	---	---	---	---
26	25	60	25	30	25	15
27	0	65	10	15	45	3
28	5	55	5	15	47	4
29	30	10	0	10	45	6
30	10	40	15	0	10	10
31	0	20	5	0	45	7
32	60	0	15	5	55	30
33	75	8	65	1	15	30
34	65	5	20	5	0	35
35	55	10	50	5	0	35
36	85	0	5	15	0	35
37	70	5	25	8	35	10
38	83	5	0	15	10	18
39	35	8	20	5	15	25
40	40	7	10	5	5	20
41	86	10	45	5	0	23
42	70	25	10	20	0	35
43	50	55	30	10	0	18
44	35	15	16	55	30	18
45	65	8	5	15	33	18

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
46	125	12	35	10	0	35
47	48	15	25	20	40	12
48	40	20	5	23	65	14
49	70	10	0	15	58	12
50	77	5	5	10	22	22
51	115	12	23	10	53	20
52	40	17	10	18	22	14
53	25	10	25	5	45	14
54	30	10	56	8	30	12
55	95	6	58	10	5	35
56	32	6	25	5	28	18
57	40	30	30	3	20	23
58	45	35	35	4	30	22
59	48	0	15	12	8	32
60	50	50	15	10	60	27
61	60	50	10	10	50	27
62	57	3	25	5	18	12
63	90	65	0	13	75	30
64	46	60	35	50	20	22
65	15	0	35	12	10	27
66	141	0	65	8	40	25
67	125	10	80	15	15	18
68	50	3	20	15	10	20
69	130	10	12	3	15	15
70	70	8	15	25	25	15
71	72	10	30	7	15	22
72	45	20	10	30	70	5
73	30	40	36	3	15	18
74	65	30	20	5	22	18
75	45	12	30	5	95	4
76	36	0	15	4	10	4
77	35	65	10	15	15	5
78	20	5	10	5	0	18
79	20	10	23	13	10	18
80	35	35	65	12	50	2
81	45	8	40	0	20	36
82	130	10	45	3	5	30
83	20	15	110	2	0	32
84	30	20	20	5	30	6
85	55	35	35	10	35	5
86	70	25	30	10	30	10
87	5	42	20	12	50	5
88	5	35	15	15	75	5
89	20	11	80	6	20	35
90	20	50	45	7	35	4
91	65	80	0	30	18	5

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
92	10	15	10	33	60	3
93	35	85	5	25	30	10
94	80	55	10	12	30	10
95	65	27	10	32	50	5
96	105	15	10	35	25	17
97	105	25	30	15	30	20
98	85	35	15	40	25	18
99	70	20	10	35	15	12
100	25	35	0	35	5	18
101	30	10	10	30	25	18
102	85	30	25	10	0	40
103	60	20	65	15	23	22
104	70	15	60	3	10	23
105	60	12	50	15	35	15
106	70	10	18	130	8	45
107	80	10	0	160	10	30
108	68	5	10	32	25	45
109	10	5	25	40	25	30
110	28	5	5	10	20	32
111	50	0	25	10	65	5
112	70	0	50	10	40	40
113	90	0	60	10	25	35
114	100	0	10	32	20	25
115	185	0	5	20	45	27
116	60	0	40	7	10	42
117	60	0	40	15	85	35
118	110	0	55	10	55	50
119	65	8	20	12	0	25
120	60	5	0	30	0	30
121	65	15	5	10	15	23
122	162	10	25	16	18	13
123	105	7	18	12	10	30
124	100	5	25	12	25	22
125	150	7	40	15	60	8
126	15	0	56	15	25	12
127	25	0	20	22	40	32
128	120	5	5	20	105	22
129	100	12	5	30	82	30
130	65	0	0	15	7	33
131	50	0	35	27	30	27
132	40	0	25	12	25	30
133	35	3	15	10	15	35
134	10	12	30	13	18	23
135	40	40	8	15	45	13
136	20	20	8	12	43	17
137	100	25	0	13	5	20

APPENDIX 5 (Contd.)

Refer to Plates

Well No.	IV	V	VI	VII	VIII	IX
138	75	9	12	17	10	23
139	10	12	55	15	15	20
140	90	8	35	11	20	18
141	100	45	15	20	65	20
142	120	60	35	20	25	15
143	25	6	58	6	20	25
144	35	6	40	10	18	27
145	115	4	30	10	30	23
146	80	60	33	12	50	18
147	15	10	5	30	20	30
148	70	---	---	---	---	---
149	80	2	0	27	30	42
150	45	3	15	15	50	47

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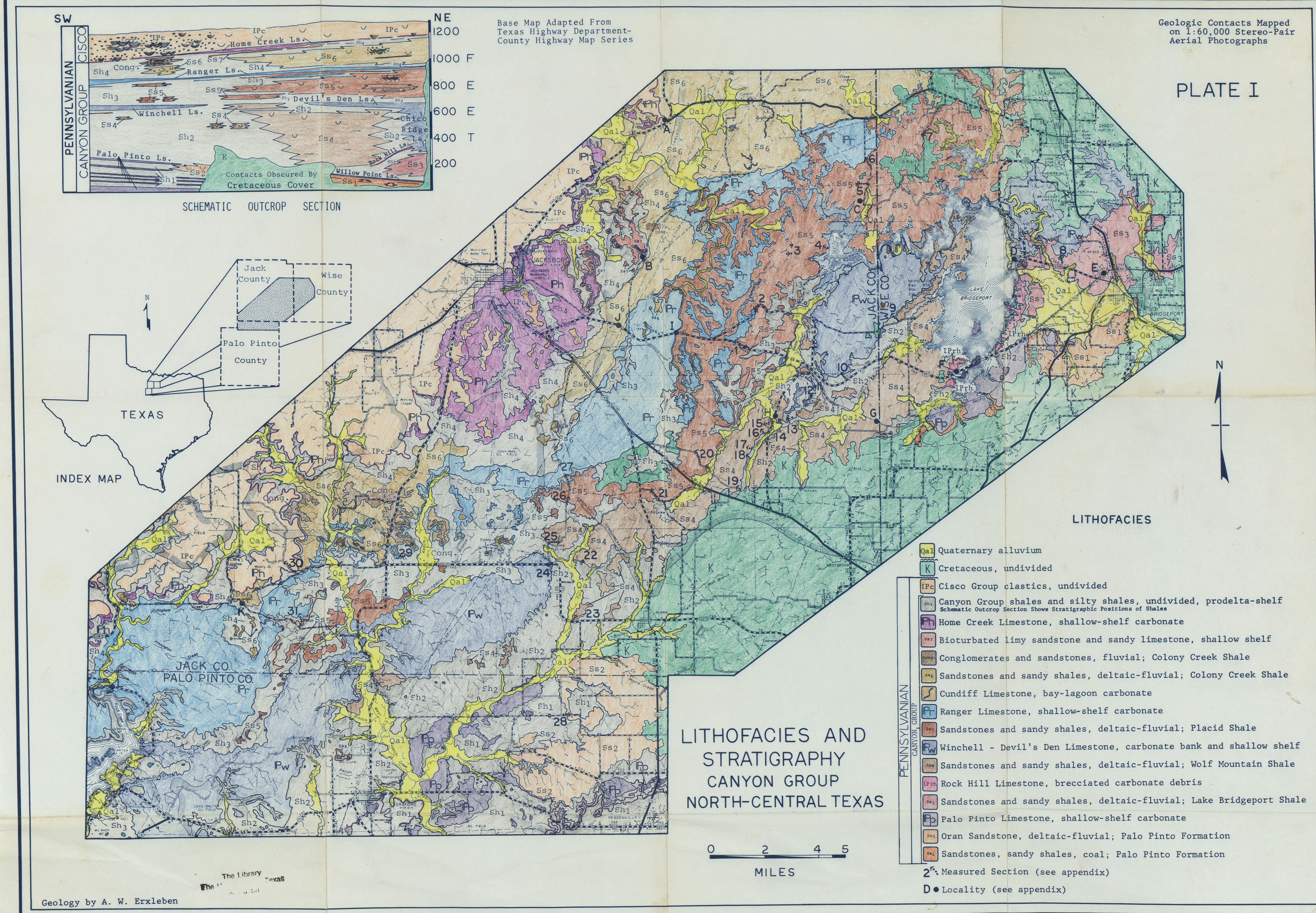


PLATE I
Base Map Adapted From
Texas Highway Department-
County Highway Map Series
Geologic Contacts Mapped
on 1:60,000 Stereo-Pair
Aerial Photographs
SW
NE
PENNSYLVANIAN
CANYON GROUP
CISCO
Home Creek Ls.
Ranger Ls.
Devil's Den Ls.
Winchell Ls.
Chico Ridge Ls.
Rock Hill Ls.
Palo Pinto Ls.
Willow Point Ls.
Contacts Obscured By
Cretaceous Cover
1200
1000 F
800 E
600 E
400 T
200
SCHEMATIC OUTCROP SECTION
Jack County
Wise County
Palo Pinto County
TEXAS
INDEX MAP
JACK CO.
WISE CO.
JACK CO.
PALO PINTO CO.
LAKE BRIDGEPORT
JACKSBORO
BRIDGEPORT
LITHOFACIES AND
STRATIGRAPHY
CANYON GROUP
NORTH-CENTRAL TEXAS
0 2 4 5
MILES
LITHOFACIES
Qal Quaternary alluvium
K Cretaceous, undivided
IPc Cisco Group clastics, undivided
PENNSYLVANIAN
CANYON GROUP
Sh3 Canyon Group shales and silty shales, undivided, prodelta-shelf
Schematic Outcrop Section Shows Stratigraphic Positions of Shales
Ph Home Creek Limestone, shallow-shelf carbonate
Ss7 Bioturbated limy sandstone and sandy limestone, shallow shelf
Cong. Conglomerates and sandstones, fluvial; Colony Creek Shale
Ss6 Sandstones and sandy shales, deltaic-fluvial; Colony Creek Shale
Cundiff Limestone, bay-lagoon carbonate
Pr Ranger Limestone, shallow-shelf carbonate
Ss5 Sandstones and sandy shales, deltaic-fluvial; Placid Shale
Pw Winchell - Devil's Den Limestone, carbonate bank and shallow shelf
Ss4 Sandstones and sandy shales, deltaic-fluvial; Wolf Mountain Shale
IPrh Rock Hill Limestone, brecciated carbonate debris
Ss3 Sandstones and sandy shales, deltaic-fluvial; Lake Bridgeport Shale
Pp Palo Pinto Limestone, shallow-shelf carbonate
Ss2 Oran Sandstone, deltaic-fluvial; Palo Pinto Formation
Ss1 Sandstones, sandy shales, coal; Palo Pinto Formation
2 Measured Section (see appendix)
D Locality (see appendix)
Geology by A. W. Erxleben

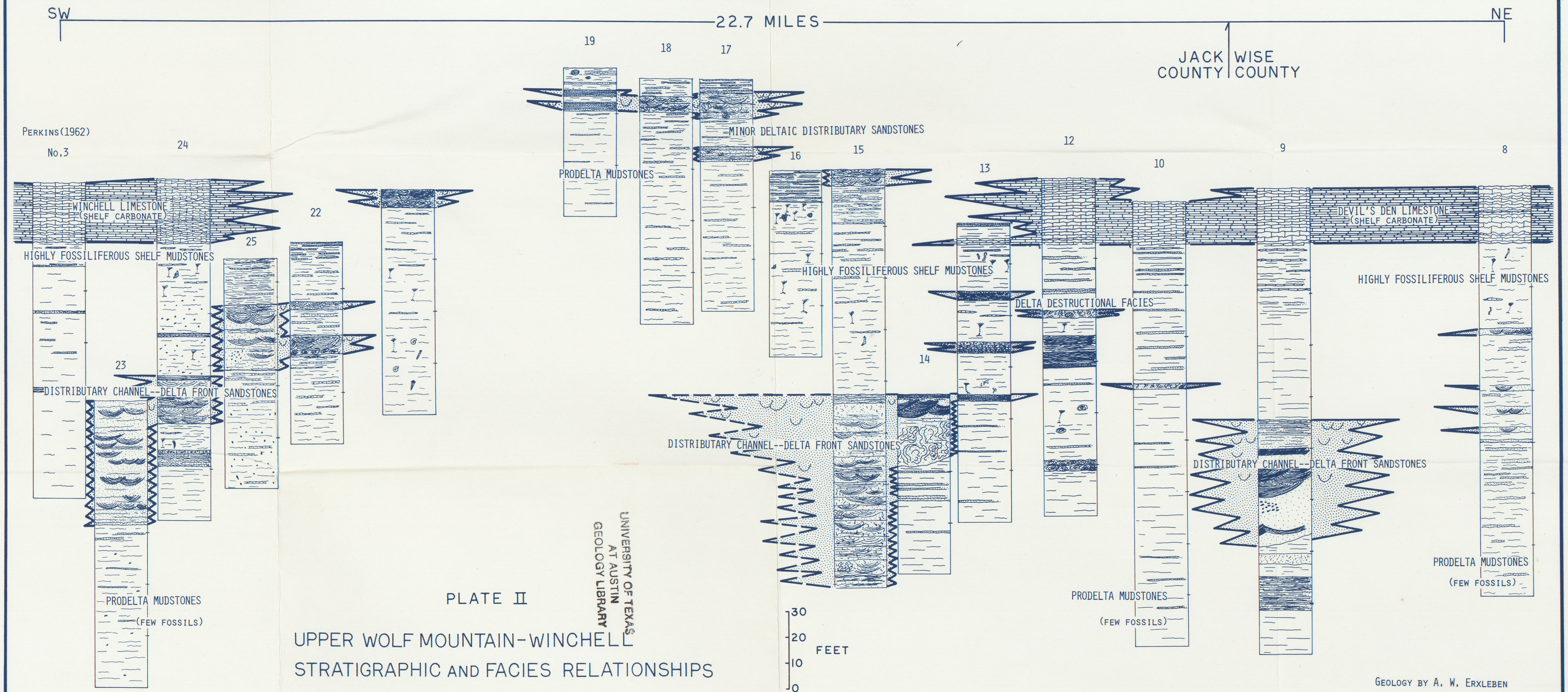


PLATE II

UPPER WOLF MOUNTAIN-WINCHELL STRATIGRAPHIC AND FACIES RELATIONSHIPS

See Appendix for Legend

Geology by A. W. Erxleben

See Appendix for Measured Section Descriptions

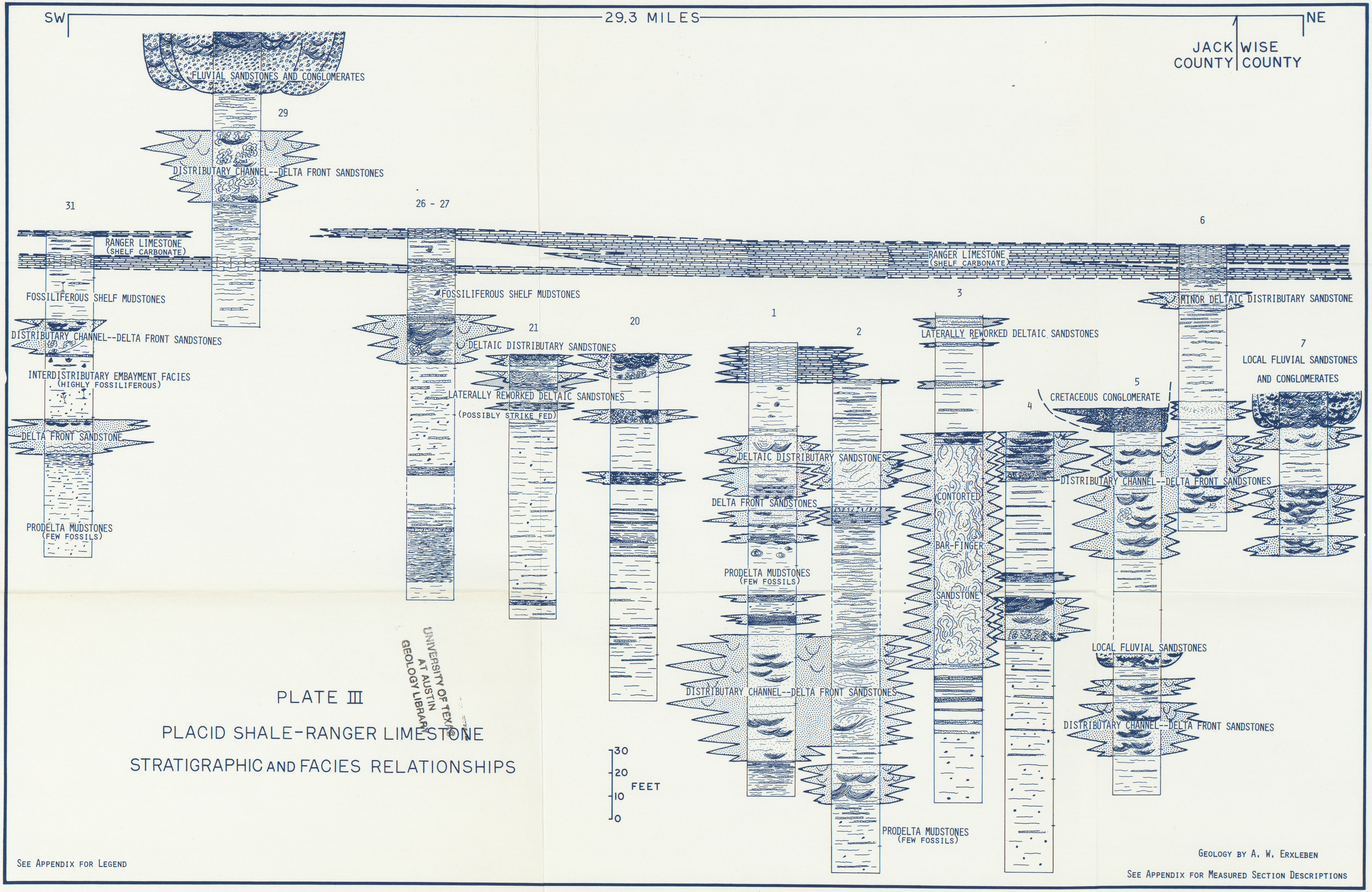


PLATE III

PLACID SHALE-RANGER LIMESTONE

STRATIGRAPHIC AND FACIES RELATIONSHIPS

SEE APPENDIX FOR LEGEND

GEOLOGY BY A. W. ERXLEBEN

SEE APPENDIX FOR MEASURED SECTION DESCRIPTIONS

PLATE IV

NET SANDSTONE THICKNESS
WOLF MOUNTAIN SHALE INTERVAL

Contour interval – 50 feet

Geology by A.W. Erxleben

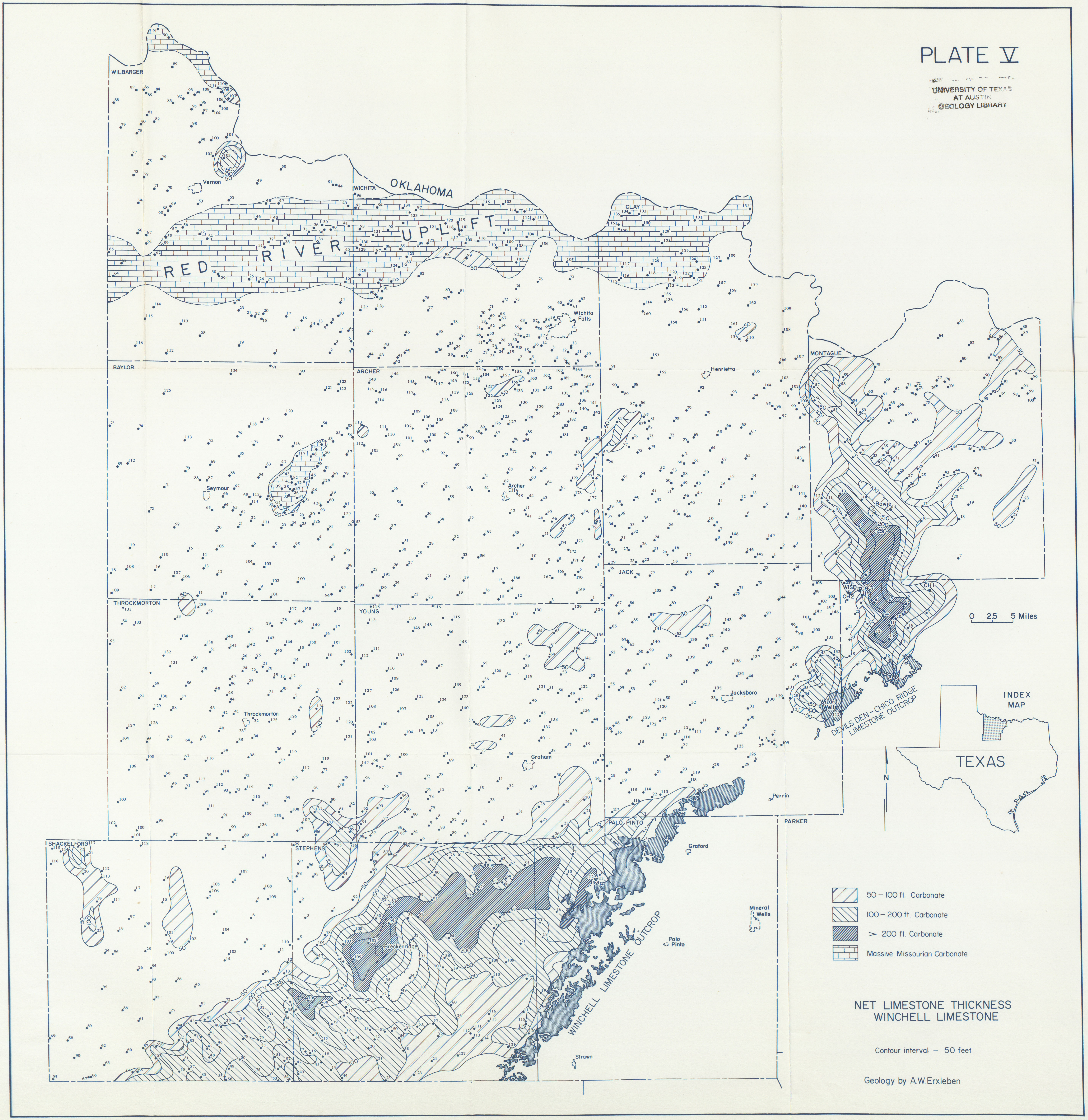
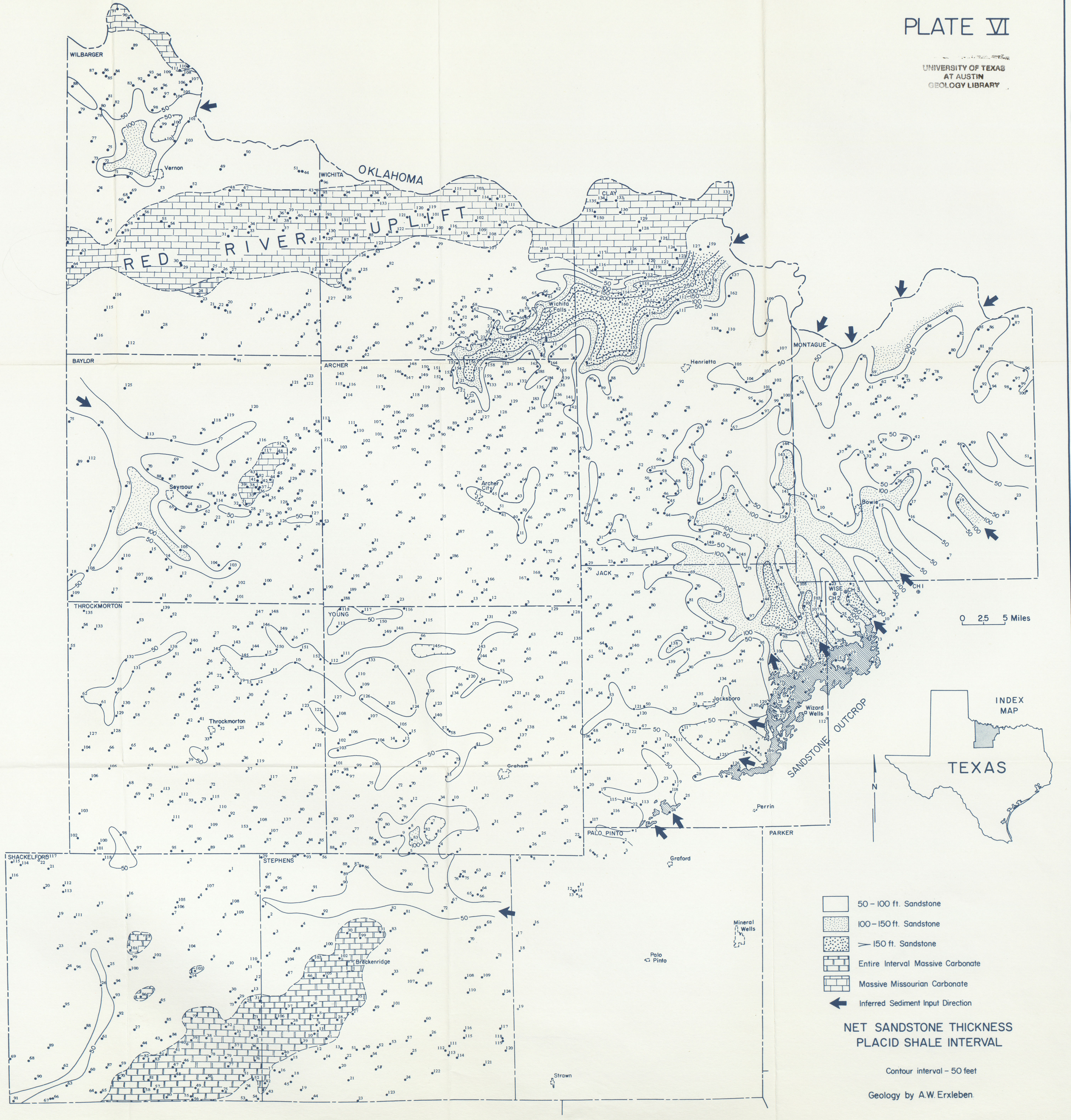


PLATE V
UNIVERSITY OF TEXAS AT AUSTIN GEOLOGY LIBRARY
OKLAHOMA
RED RIVER UPLIFT
WILBARGER
WICHITA
CLAY
MONTAGUE
BAYLOR
ARCHER
THROCKMORTON
YOUNG
JACK
WISE
SHACKELFORD
STEPHENS
PALO PINTO
PARKER
Vernon
Wichita Falls
Henrietta
Seymour
Archer City
Bowie
Jacksboro
Throckmorton
Graham
Perrin
Graford
Mineral Wells
Palo Pinto
Breckenridge
Strawn
Wizard Wells
CH1
CH2
DEVILS DEN - CHICO RIDGE LIMESTONE OUTCROP
WINCHELL LIMESTONE OUTCROP
0 2.5 5 Miles
N
INDEX MAP
TEXAS
50 – 100 ft. Carbonate
100 – 200 ft. Carbonate
> 200 ft. Carbonate
Massive Missourian Carbonate
NET LIMESTONE THICKNESS WINCHELL LIMESTONE
Contour interval – 50 feet
Geology by A.W.Erxleben

PLATE VI



NET SANDSTONE THICKNESS
PLACID SHALE INTERVAL

Contour interval – 50 feet

Geology by A.W. Erxleben

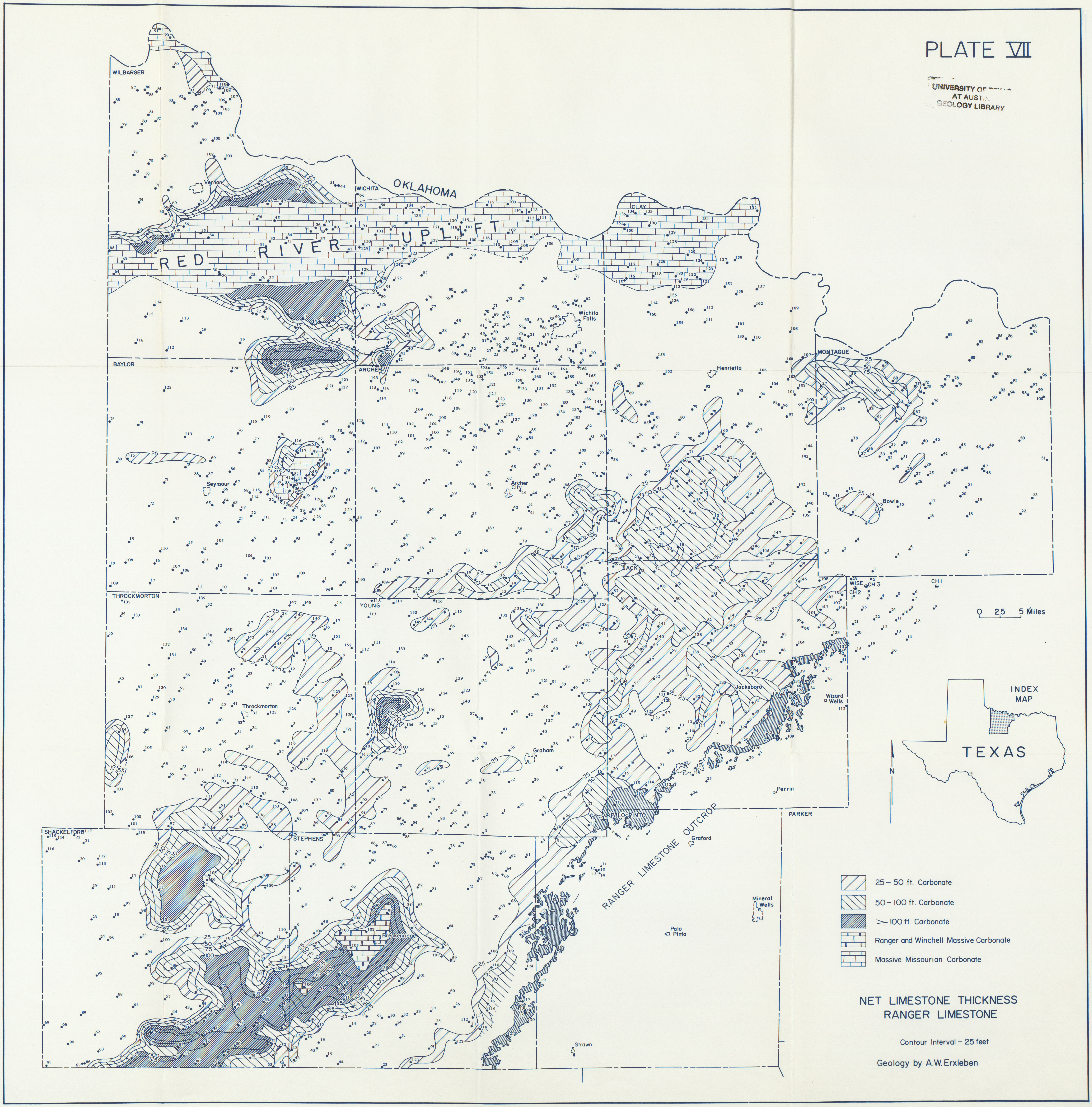


PLATE VII
WILBARGER
Vernon
WICHITA
OKLAHOMA
RED RIVER UPLIFT
CLAY
Wichita Falls
MONTAGUE
Henrietta
BAYLOR
ARCHER
Seymour
Archer City
Bowie
THROCKMORTON
YOUNG
JACK
WISE
CH 1
CH 2
CH 3
0 2.5 5 Miles
Throckmorton
Graham
Jacksboro
Wizard Wells
INDEX MAP
TEXAS
N
Perrin
PALO PINTO
PARKER
SHACKELFORD
STEPHENS
Graford
RANGER LIMESTONE OUTCROP
Mineral Wells
Palo Pinto
Breckenridge
Strawn
25 – 50 ft. Carbonate
50 – 100 ft. Carbonate
> 100 ft. Carbonate
Ranger and Winchell Massive Carbonate
Massive Missourian Carbonate
NET LIMESTONE THICKNESS
RANGER LIMESTONE
Contour Interval – 25 feet
Geology by A.W. Erxleben

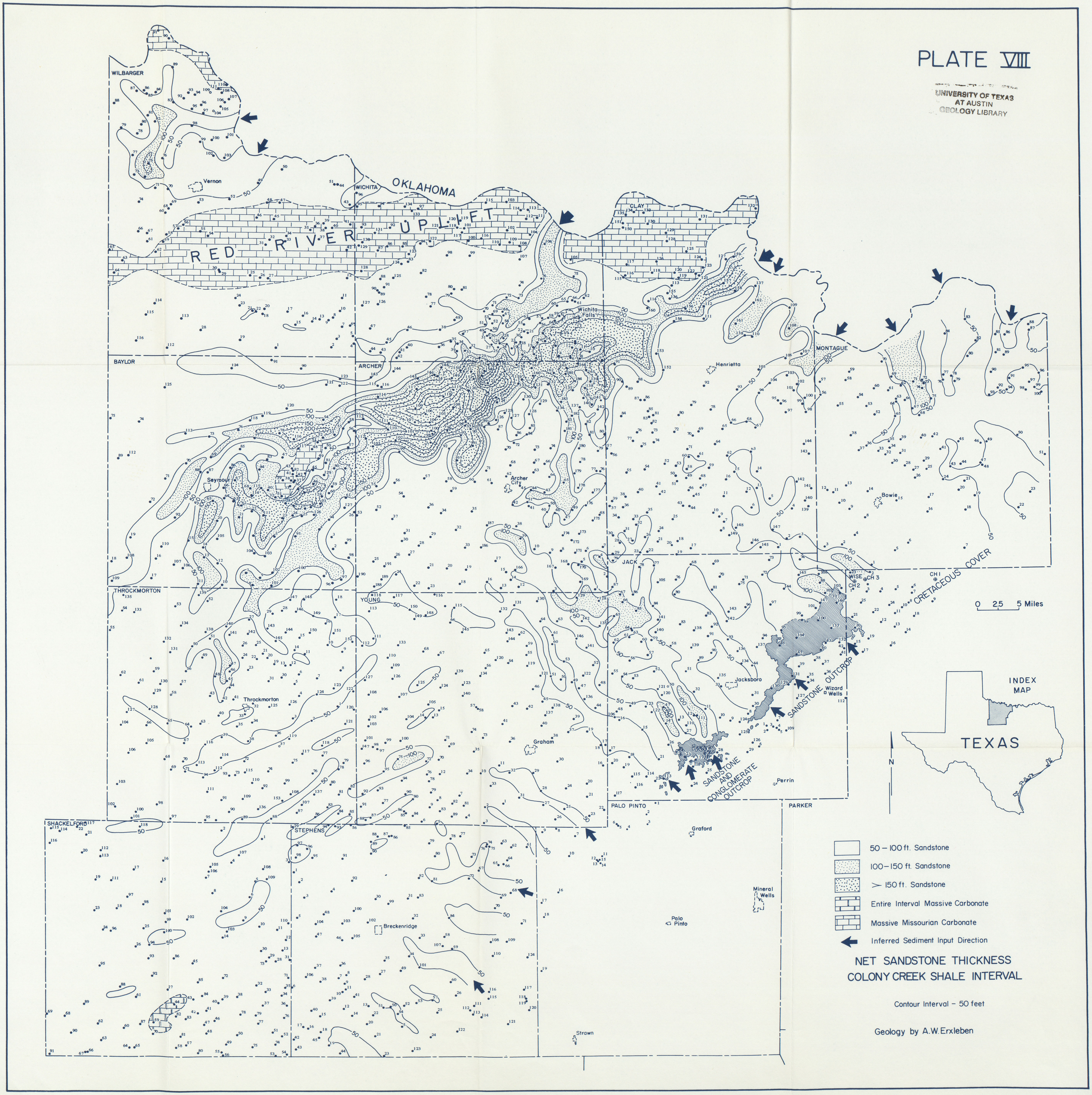


PLATE VIII
UNIVERSITY OF TEXAS AT AUSTIN GEOLOGY LIBRARY
WILBARGER
Vernon
WICHITA
OKLAHOMA
RED RIVER UPLIFT
CLAY
Wichita Falls
MONTAGUE
Henrietta
BAYLOR
ARCHER
Archer City
Seymour
Bowie
THROCKMORTON
Throckmorton
YOUNG
Graham
JACK
Jacksboro
WISE
CH 1
CH 2
CH 3
CRETACEOUS COVER
SANDSTONE OUTCROP
SANDSTONE AND CONGLOMERATE OUTCROP
Wizard Wells
Perrin
0 2.5 5 Miles
INDEX MAP
TEXAS
N
SHACKELFORD
STEPHENS
Breckenridge
PALO PINTO
Graford
Palo Pinto
Mineral Wells
PARKER
Strawn
50 – 100 ft. Sandstone
100 – 150 ft. Sandstone
> 150 ft. Sandstone
Entire Interval Massive Carbonate
Massive Missourian Carbonate
Inferred Sediment Input Direction
NET SANDSTONE THICKNESS
COLONY CREEK SHALE INTERVAL
Contour Interval – 50 feet
Geology by A.W. Erxleben

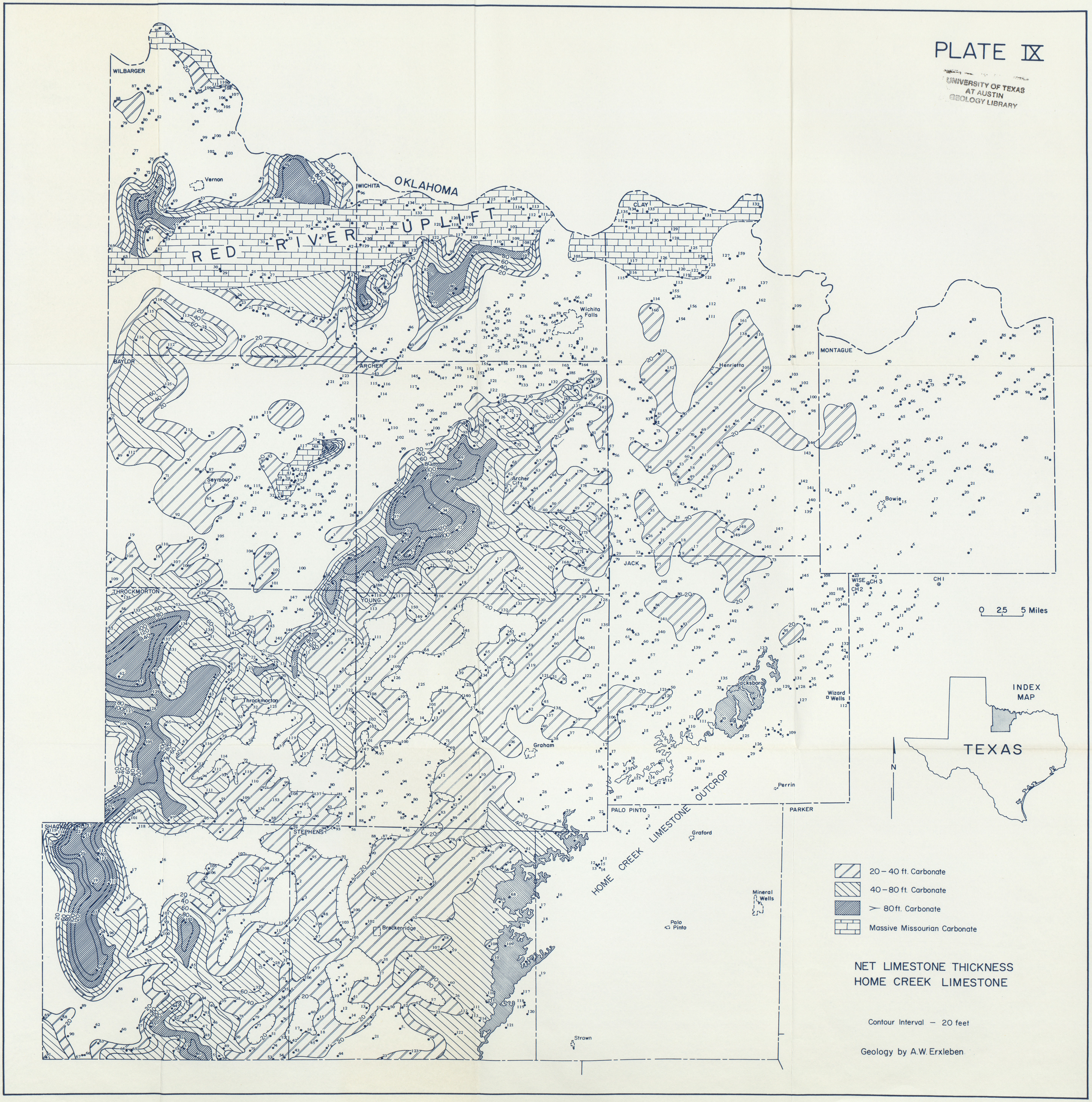


PLATE IX
WILBARGER
WICHITA
OKLAHOMA
CLAY
RED RIVER UPLIFT
Vernon
Wichita Falls
BAYLOR
ARCHER
Henrietta
MONTAGUE
Seymour
Archer City
Bowie
THROCKMORTON
YOUNG
JACK
WISE
CH 3
CH 2
CH I
0 2.5 5 Miles
Throckmorton
Jacksboro
Wizard Wells
INDEX MAP
TEXAS
Graham
Perrin
N
SHACKELFORD
STEPHENS
PALO PINTO
PARKER
HOME CREEK LIMESTONE OUTCROP
Graford
Mineral Wells
Breckenridge
Palo Pinto
Strawn
20 – 40 ft. Carbonate
40 – 80 ft. Carbonate
> 80 ft. Carbonate
Massive Missourian Carbonate
NET LIMESTONE THICKNESS
HOME CREEK LIMESTONE
Contour Interval – 20 feet
Geology by A.W. Erxleben